BULLETIN

OF THE

UNIVERSITY OF TEXAS

1915: No. 62

NOVEMBER 5 1915

Bureau of Economic Geology and Technology

J. A. Udden, Director

Road Materials of Texas

BY

JAMES P. NASH
TESTING ENGINEER

Published by the University six times a month and entered as second-class matter at the postoffice at
AUSTIN, TEXAS

Publications of the University of Texas

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B169-1015-3m

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PUBLICATIONS OF THE BUREAU OF ECONOMIC GEOLOGY AND TECHNOLOGY

The Mineral Resources of Texas. Wm. B. Phillips. Issued by the State Department of Agriculture as its Bulletin No. 14, July-August, 1910. (Out of print.)

The Composition of Texas Coals and Lignites and the Use of Producer Gas in Texas. Wm. B. Phillips, S. H. Worrell, and Drury McN. Phillips. University of Texas Bulletin No. 189, July, 1911. (Out of print.)

A Reconnaissance Report on the Geology of the Oil and Gas Fields of Wichita and Clay Counties. J. A. Udden, assisted by Drury McN. Phillips. University of Texas Bulletin No. 246, September, 1912.

The Fuels Used in Texas. Wm. B. Phillips and S. H. Worrell. University of Texas Bulletin No. 307, December 22, 1913.

The Deep Boring at Spur. J. A. Udden. University of Texas Bulletin No. 363, October 5, 1914. (Out of print.)

The Mineral Resources of Texas. Wm. B. Phillips. University of Texas Bulletin No. 365, Scientific Series No. 29, October 15, 1914.

Potash in the Texas Permian. J. A. Udden. University of Texas Bulletin No. 17, March 20, 1915. (Out of print.)

Geology and Underground Waters of the Northern Llano Estacado. Charles Lawrence Baker. University of Texas Bulletin No. 57, October 10, 1915.

Address all communications to:

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University Station, Austin, Texas.

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ILLUSTRATIONS.

FOREWORD

The coming of the horseless vehicles has given a great impetus to the building of good roads. Our citizens are now spending larger sums than ever before to open and to improve rural and intercurban routes of communication. In the apparent simplicity of the engineering problems connected with such improvements, there lurks the danger of inefficient direction and supervision of the work for which the public is taxed. In this part of the world we have had comparatively little experience in the art of building public highways. We have hardly yet learned to appreciate the value of technical knowledge acquired in this line in other lands, and in our own country.

To Dr. Wm. B. Phillips, the former Director of this Bureau, is to be given great credit for seeing and providing for the need of technical guidance in road building in this state. This need is not so much in the lack of engineers to direct local efforts. Such men are now, thanks to the departments of engineering in our educational institutions, found in most communities. It is rather in the lack of facilities afforded engineers to apply standard tests to the materials with which they work. Such tests are needed by all practicing engineers, and they can be made only in well equipped and competently manned laboratories.

In September, 1914, Mr. James P. Nash, of the U. S. Office of Public Roads at Washington, was engaged by this Bureau to take charge of the roads materials testing laboratory inaugurated at that time. In the following pages he presents his first report on the tests so far made on Texas materials. He couples this with a lucid and practical presentation of the classification and properties of road materials in general. Together with his descriptions of the nature of tests made and of the apparatus used in the laboratory, it is believed the data published should be of great practical value to all present and prospective road builders in Texas, especially at this time, when so much road work all over the state is either in contemplation or already under way.

J. A. Udden, Director.

Austin, Texas, November 22, 1915.

INTRODUCTION.

In modern engineering practice, it has been found that for economy and safety, and for the betterment of the materials themselves, they should be tested; and their properties, especially their physical properties, be determined. This is true of road materials; with the exception, perhaps, that the economic question encroaches upon the safety factor to a considerable extent. Many of the materials have been used in road construction and their value established by a practical test; but this is an expensive method, if the material proves worthless. In fact, it is from a large number of these practical tests that present laboratory practice has been built. The successes and failures have been studied and tests devised to duplicate the actions of traffic: the element of time being eliminated.

In the case of road materials, it is generally difficult to obtain those materials which have proven successful, without considerable expense, and the road builder is obliged to use the best materials in the vicinity of the work.

The object of the Road Materials Testing Laboratory is to study the road material question in Texas, and aid the road builder in the selection of the proper material for each locality. If many materials are available, it is well to know which is the best to use; or to ascertain if it would not be cheaper to bring material from a distance rather than use a poorer quality which may be at hand. Or the question may be simply—what constitutes a good road material and where it can be found?

Laboratories similar to the one in the Bureau of Economic Geology and Technology are being conducted by most of the Highway Commissions now existing, and are considered one of their essential parts.

It is the purpose of this bulletin to discuss briefly the properties of road materials in Texas, so far as known from the tests which have been made; and the practical application of the facts ascertained, so that the results of the tests may be more readily interpreted. The table of all the tests made will be found in the appendix with brief remarks as to the value of each material tested.

CHAPTER I

GENERAL DISCUSSION

Necessary Qualities of Roads

A road, no matter what the type of material used, must be built so that it will withstand, to a greater or less degree, four kinds of destructive agencies—bacterial, chemical, physical, and mechanical.

Bacterial action has little place in the broken-stone road except the slight action of the acids evolved by bacteria in decaying animal excreta. This is negligible, and will not be considered further. In the case of gravel or sand-clay construction, however, the decaying of wood or trees roots often causes potholes that can be avoided by keeping such materials out while the road is being constructed. It is partly for protection from the action of bacteria, also, that wood blocks are treated.

Chemical action is also quite negligible, and will not be considered here.

Under physical agencies, are considered the effects of rain, wind, and temperature. A heavy rain tends to gouge out channels in the road, and, unless properly guarded against, this will eventually destroy the road. This is more true of a sand-clay or gravel road than of the better types of construction. Even a light rain tends to wash away the binder, and will soften the sub-grade if allowed to reach it. Wind acts as a broom to sweep away any fine material not compacted with a binder. Large variation in temperature causes expansion and contraction which must be cared for, but the effect of this variation is not felt on the macadam or gravel road. Frost has a disintegrating effect on stones which have high absorption. This need not be given much consideration, however, as most of the material which is hard enough to use is usually dense enough to have a small absorption. In Texas, the winters are short and comparatively mild, with little frost.

The mechanical agencies are the most important, as they embrace the real destructive forces on the road, which the surfacing materials must withstand. These include the impact of horses' hoofs and of heavy teams; the wearing action of steel tires, especially narrow ones; and the shearing force of motor vehicles, which has become one of the most formidable agencies of all. Narrow tires are unnecessary, and their use should be discontinued, as their tendency to sink into the surface renders them a great destructive agent of good roads.

Properties necessary in road materials

Granted that all the engineering essentials of a good road, such as alignment, grade and drainage, are properly taken care of, a road will yet be poor if the proper material is not used in its construction. As this constitutes the greatest expense of the highway, it is essential that the material be one which will best resist all the above destructive agencies at the smallest price.

Rock for water-bound macadam roads

A rock must have a certain degree of hardness in order to resist the friction of traffic, which tends to wear it into dust. This tendency is not only on the surface of the road, but is transmitted to the interior, and if the stones are not firmly interlocked there will be friction and a small amount of wear. It is further essential that a rock be tough enough to resist the impact of horseshoes and of steel-tired vehicles. This impact is more destructive on the smaller stones, as they have less body to resist the blow.

The binding property of the rock dust is an important factor in water-bound macadam roads. It is this property which causes the road to cake into a hard, smooth and impervious surface. If this binding property is lacking, the dust worn off the rocks by traffic will remain inert on the road or be blown away, causing the surface to ravel. This cementing property is different from that developed in hydraulic cement, as it is more of a mechanical quality, resulting in the interlocking of the fine particles with each other, in combination with a certain amount of plasticity. Some rocks, like limestone, owe a small degree of their cementing value to chemical action.

The relation of the various types, and tests of these rocks, will be considered later.

Rocks for bituminous macadam roads

In this type of construction it is unnecessary that a rock should possess cementing value, as the bond is supplied by the bituminous material; nor is it necessary that a rock should possess toughness to a high degree, as the road itself is resilient under impact, and the stones, individually, are relieved of pressure. This permits the use of stone that would be unsatisfactory in water-bound macadam. Another important consideration in this connection is the characteristic fracture of the rock when crushed. This property varies with the type of material. The absorption of the rock also has considerable influence on the adhesion of the bitumen.

Gravels are unsatisfactory in bituminous construction, owing to the presence of round and smooth stones which will not permit a firm bond. This objection is not to be considered, when the bitumen is used only in a surface cover. Such surface treatment over a compact gravel gives very good results.

Road-building gravels

A road-building gravel consists of a combination of more or less rounded fragments of rock varying in size and form, shaped and combined by nature. It may or may not contain fine material derived from the disintegration of rocks. Shell gravels may be defined in a similar manner, except that the shells replace the rock.

The properties needed to resist the wear on a gravel road are the same as are necessary in any type of road, except that they are obtained in a slightly different manner. The large stones must be hard and tough, as they are called upon to support the traffic. The voids among the larger stones are filled with sand, bonded into a compact mass by a natural bonding material such as clay. The resulting mass is similar to concrete, except that the plastic clay replaces the hydraulic cement.

To obtain a hard, impervious road it is necessary that the gravel be fairly well graded, from the largest stones, about two inches in size, down to very fine material. All stones larger than 2½ inches should be removed either by screening or raking, as they invariably come to the surface in a short time, causing unnecessary roughness and uneven wear.

Clay should be definite in amount, and possess good binding properties. Clays of a plastic nature hold the particles of sand and stone together and produce a much more compact road than those not possessing this property. Oxide of iron is a very good binder itself and the red clays which contain it are excellent binders.

It is sometimes considered a good property in clay that it resists slaking. This is the property which enables it to resist disintegration in water after it has become dried and hard. Tests have been made in the laboratory to ascertain if any relation exists between the slaking and the cementing value of specimens of sand and clay; but none was found to exist.

Bituminous gravel roads generally have not proven a success, but surface treatment is an excellent method of caring for a gravel which contains little binder. By this method, a gravel which would otherwise be unsatisfactory for use because of the lack of a binder, may be used with good results. Epecially is this true in Texas, where gravel is so prevalent.

Sand-clay materials

The theory of the sand-clay road is simple enough. A wet sand will support traffic, and so will a dry clay; therefore, a judicious combination of the two will have the advantages of both. This combination should contain enough clay to fill the voids in the packed sand; usually about 25 per cent. clay and 75 per cent. sand. The best mixture is a matter to be determined by the results on the road. The sand should be clean and sharp; while the clay, like that used in a gravel, should be plastic and sticky, to bind the sand. The character of materials and methods of constructing this type of road are such that the making of physical tests of such materials is not warranted.

Asphaltic oils have been used in this type of road, but are uneconomical unless the oil can be purchased very cheap.

Other paving materials

With the higher class of paving materials, such as brick, granite and wood block, concrete, rock asphalt, asphalt, and many of the patented pavements, the resistance to destruction is taken care of either in the individual blocks themselves or in the pavement as a whole. It is necessary that paving materials be tough and have a high resistance to wear. Their absorption should be low. This is usually the case, as may be inferred from the nature of the materials used. Wood block is the most susceptible to absorption. The choice of these materials is a matter of local opinion as to cleanliness, noiselessness and wear. They are all recognized as making good pavements, and their use in Texas is confined mainly to city streets.

CHAPTER II

THE TESTING OF MATERIALS

The Testing of Road-building Rock

The physical tests made on road-building rocks to determine their value are as follows: (1) hardness; (2) toughness; (3) resistance to wear; (4) cementing value; (5) specific gravity; (6) absorption; and (7) compression. These tests are described in Bulletin 44 of the Office of Public Roads, Washington, but will be briefly discussed here.

The hardness test, which determines the resistance of the rock to disintregation from friction, is made in the Dorry Hardness machine shown in Plate I, which was first devised by the French School of Roads and Bridges in a modified form. The test is made on a core one inch in diameter, drilled from the rock, and placed in a spool-shaped receptacle, which holds it vertically against the revolving disc under standard pressure. The disc is fed continually from the hoppers with a standard crushed quartz between 30 and 40 mesh sieve. This crushed quartz acts as an abrasive agent. Two cores are run at the same time for 1,000 revolutions and the average of the two is taken in computing the coefficient of hardness. This is derived by weighing the specimen before and after the run, dividing the loss in weight by 3, and subtracting the result from the arbitrary number 20. The degree of hardness varies, therefore, from 0 to 20, with the latter figure as a maximum. If it falls below 14, it is considered as soft; from 14 to 17, as medium hard; and above 17, as hard.

The toughness test is made on the rock to determine its resistance to impact. It is made in the machine shown in Plate II, devised by Director L. W. Page, of the Office of Public Roads at Washington, on the pile driver principle. The specimen used is a rock cylinder 1 inch in diameter, and 1 inch in height. It is tested by dropping a two kilogram weight on the specimen through the medium of a steel cylinder whose curved lower surface remains in contact with the center of the rock specimen. The hammer is dropped from a height which is increased by increments of one centimeter (.4 inches) from one until the

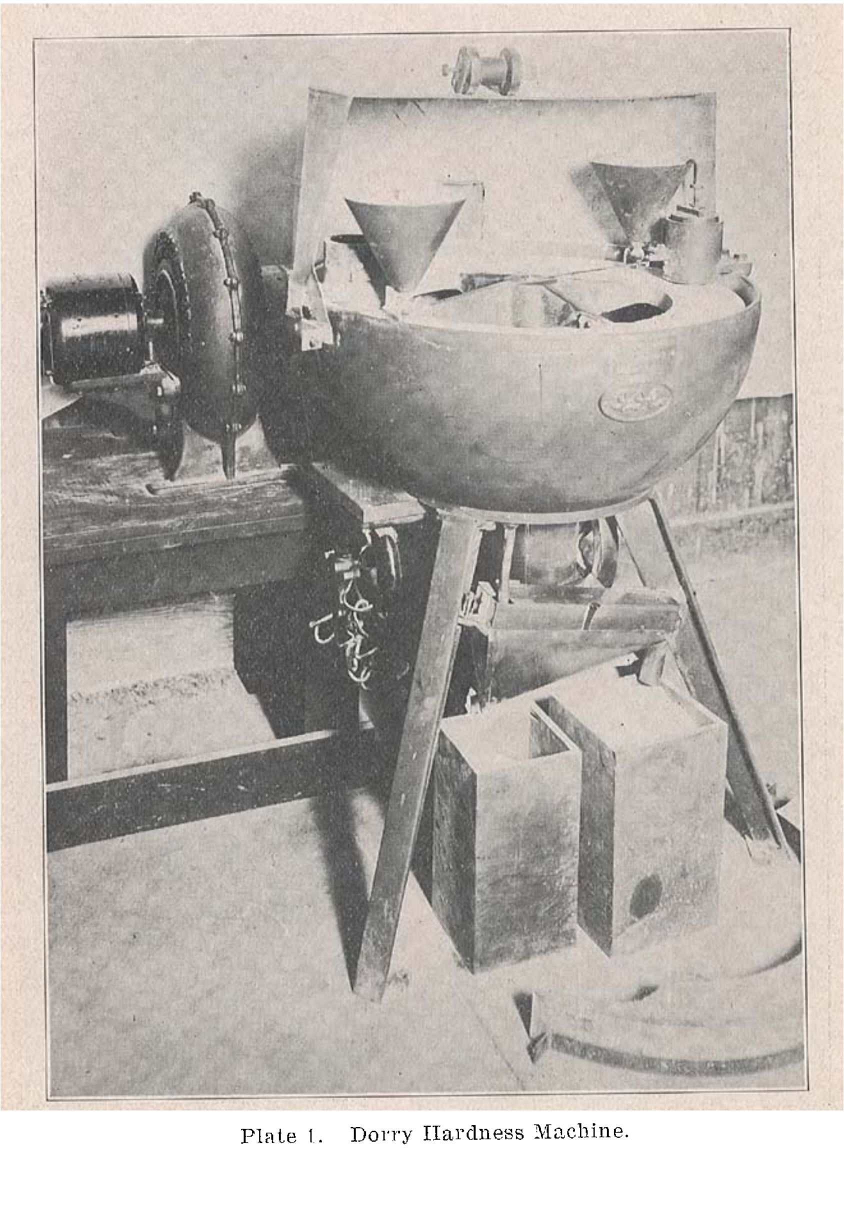

Plate 1. Dorry Hardness Machine.

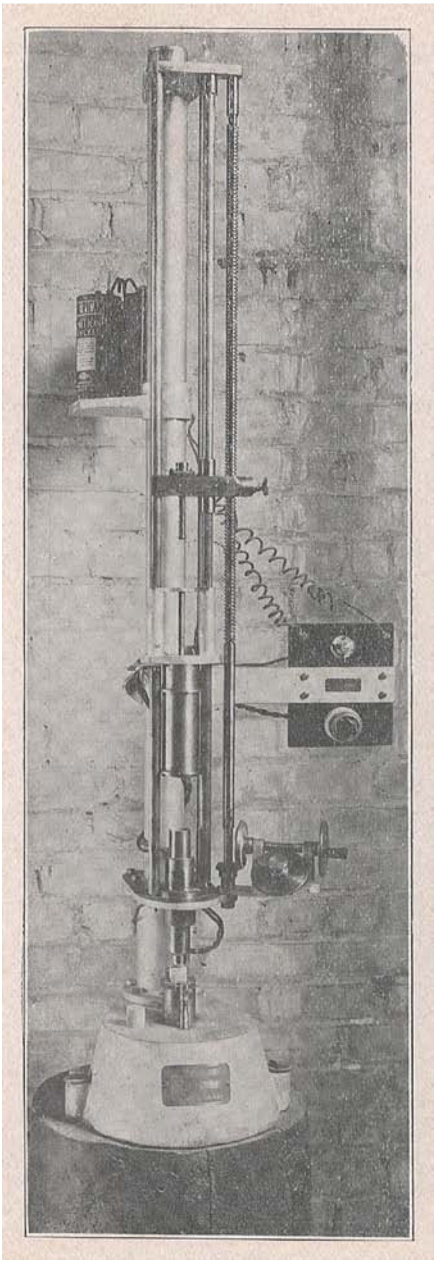

Plate 2. Impact Machine for Toughness Testing.

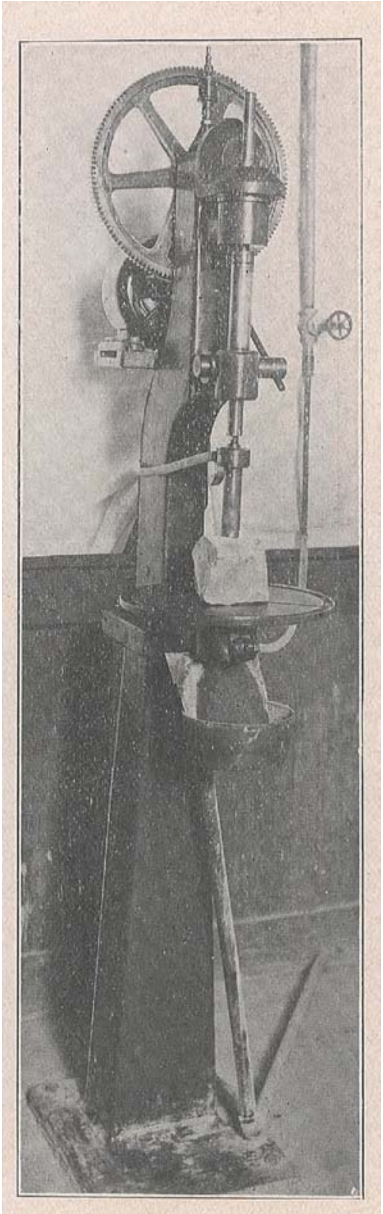

Plate 3. Diamond Core Drill.

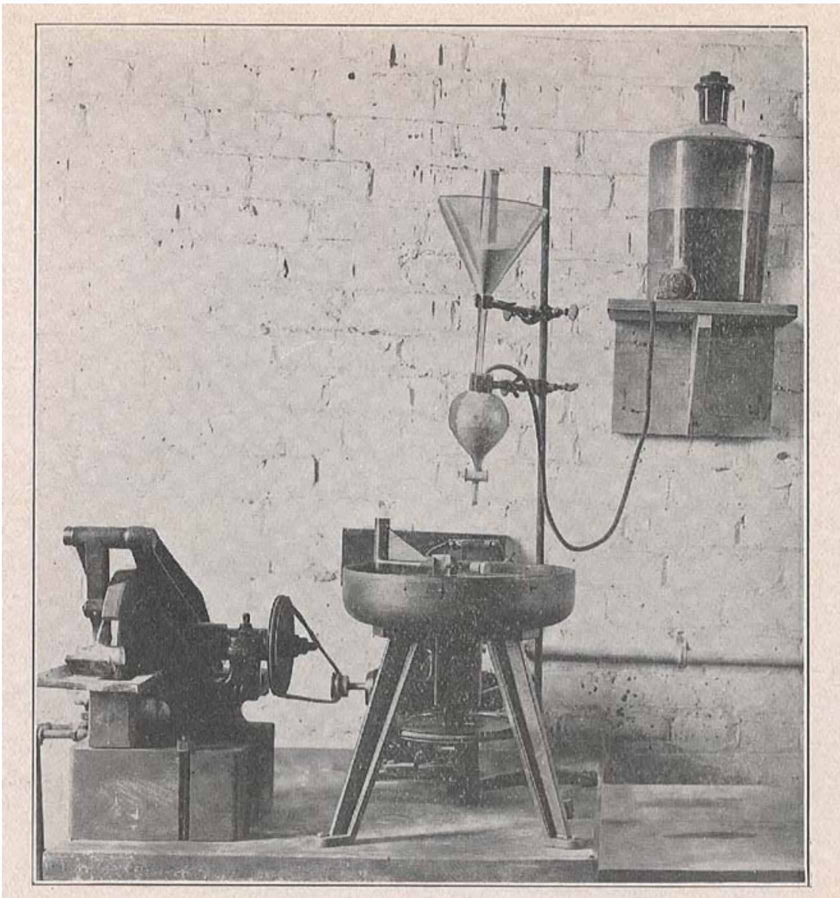

Plate 4. Diamond Saw and Lap Grinder.

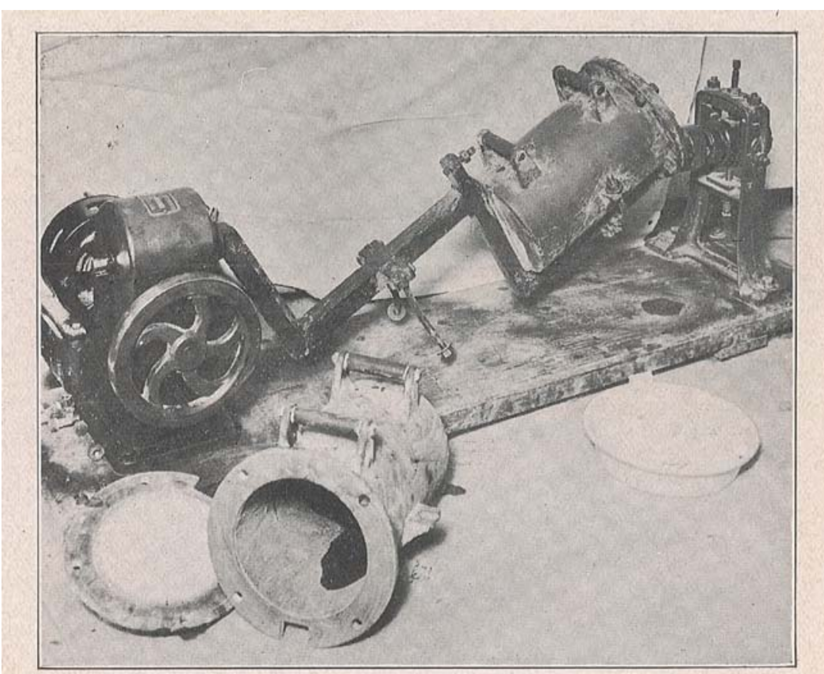

Plate 5. Duval Abrasion Machine.

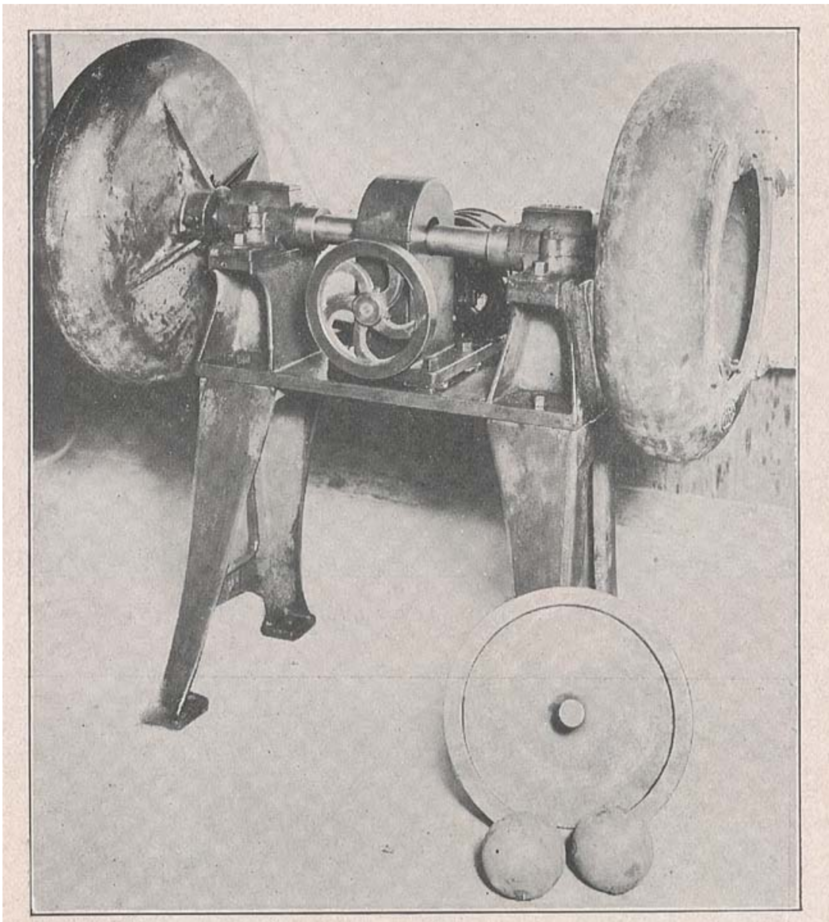

Plate 6. Two Drum Ball Mill for Cementation Test.

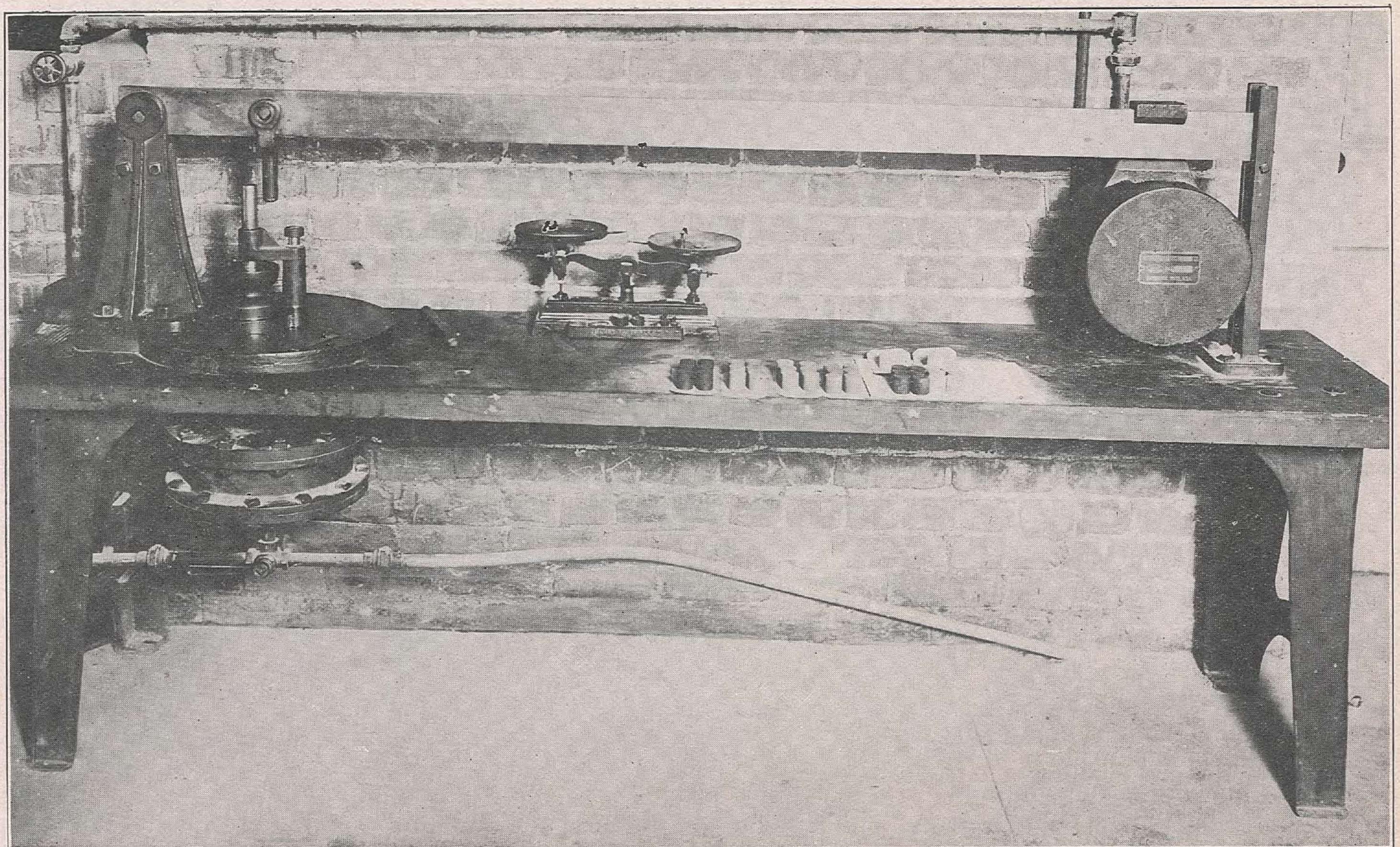

Plate 7. Hydraulic Press for Forming Cementation Briquettes.

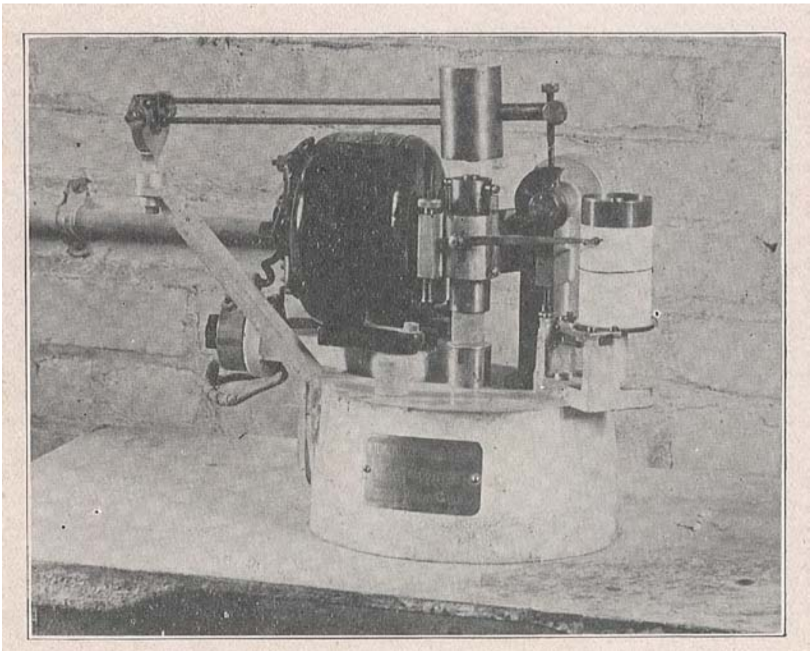

Plate 8. Page Impact Machine for Cementation Test.

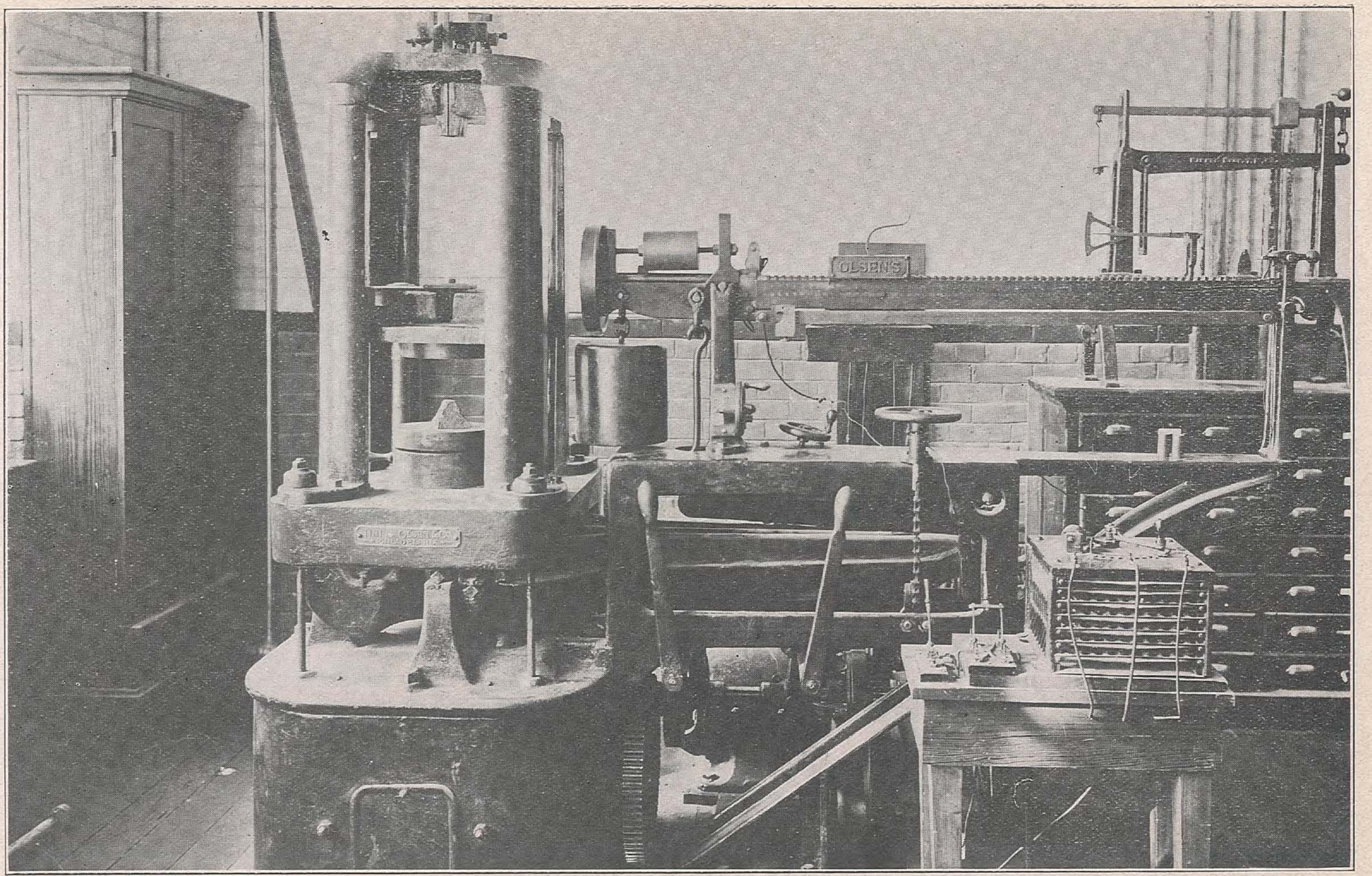

Plate 9. Olsen 100,000 Pound Testing Machine.

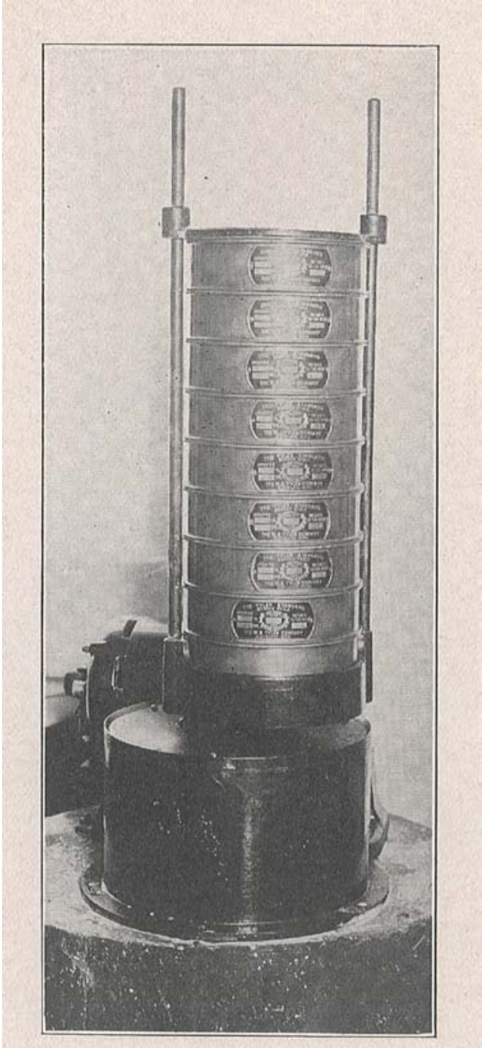

Plate 10. Mechanical Sieving Device.

specimen breaks, which it usually does by splitting into two or three equal parts. The number of blows, which also represents the height of the last blow, measured in centimeters, is the numerical toughness. If the rock fails in less than 13 blows it is considered as having low toughness; from 13 to 19, as medium; and above 19, as high. The average of two tests is taken.

The rock core used in both the hardness and toughness test is drilled from the rock by means of the diamond core drill shown in Plate III, cut and faced to the required size by means of the diamond saw and lap shown in Plate IV.

The abrasion test, also devised by the French School of Roads and Bridges, is made on the rock to determine its resistance to wear under traffic conditions. This test is made in the Standard Deval Abrasion machine shown in Plate V. By revolving the rock sample in one of the cast iron cylinders which rotates at an angle of 30 degrees to the horizontal, the rock is thrown from one end of the cylinder to the other and back, upon each revolution; ten thousand such revolutions constituting the test. The sample consists of rock broken by hand in sizes so that approximately 50 pieces will weigh 5,000 grams (11 pounds). This throwing of the rock from one end of the cylinder to the other causes the stones to wear upon themselves and to impact against the ends of the cylinder. The fine dust resulting from this wear is screened out and the stone reweighed, the loss being expressed in per cent. and also by the French coefficient of wear. This coefficient is obtained by dividing the per cent. of wear into 40. The best wearing rocks have a per cent. of wear of 2 or coefficient of 20. If this coefficient of wear is below 8, it is considered as low; from 8 to 13, medium; from 14 to 20, high; and above 20, very high.

The *cementation test* is made on the rock to ascertain to what extent the fine material will bind into a hard, impervious crust in a water-bound macadam road. It is made by grinding a definite quantity of the rock with a standard amount of water in the ball mill with two steel balls. The double ball mill is shown in Plate VI with the mill on the right, open. After 5,000 revolutions in this mill, the rock dough is made into cylindrical briquettes 25 millimeters (1 inch) in diameter and 25 mm. (1 inch) in height, under a pressure of 132 kilograms per square centimeter (about 1,800 lbs. per square inch) in the hydraulic press shown in Plate VII. These briquettes are allowed to remain in air 20 hours at room temperature, and 4 hours more at 100 deg. C. (212 deg. F.), after which they are cooled and tested in the Page Impact machine for cementation tests, shown in Plate VIII. This allows a 1 kilogram (2.2 lb.) hammer to drop 1 centimeter (.4 inches) until the specimen breaks. The number of blows required to break the specimen is recorded automatically on a sheet of paper so that a permanent record is kept. The cementing value is considered as being low if below 10 blows; between 10 and 25, as fair; between 25 and 75, good; 75 to 100, very good; and above this, as excellent.

The *specific gravity* is obtained of all rock samples by weighing the dried specimen in air and then in water, setting the weights on the balance to approximate the weight in water, before immersion.

The absorption is derived by allowing the rock to remain in water for 96 hours and is reported in pounds of water absorbed per cubic foot of solid rock

As most crushed stone is bought by the ton, it is necessary to know the weight of a cubic foot of the material. The weight of a cubic foot of solid rock is obtained by multiplying the weight of a cubic foot of water, or 62.4 pounds by the specific gravity. Knowing the voids in the crushed stone, its weight per cubic foot can be calculated by subtracting from the weight of a cubic foot of the solid rock, the weight of rock represented by the voids. This may be reversed and the voids found, if the weight of loose stone is known.

The *compression test* is made on rock to determine the weight it will carry without rupture. A road-building rock is not required to have such resistance to compression to any marked degree, but in testing material for railroad ballast or building stone, the determination of compression strength is demanded. It is also a good test for concrete aggregate, stone block or brick paving material. A two-inch cube bedded in plaster of paris is used as the specimen to be tested. It is broken in the 100,000 pounds testing machine shown in Plate IX. To be recommended for a railroad ballast, it is necessary that the rock should have a compressive strength greater than 10,000 pounds, besides showing up well in the other tests.

The relation of the tests to one another

In a paper presented before the 1913 convention of the American Society for Testing Materials, L. W. Page showed the relation of various road material tests to one another. The relation between the hardness and toughness tests was brought out in a curve which showed that for high toughness, the hardness is invariably high, but when the toughness is low, the hardness may be either high or low. A somewhat similar relation was established between the toughness and the abrasion tests. It was shown that where a high toughness exists, a low per cent of wear is found. As in the case of the hardness test, a low toughness rock may develop either a high or low per cent of wear. Between the abrasion and hardness tests no relation could be definitely established.

Since the establishment of the testing laboratory at this Bureau, about four hundred tests have been made, of which about half have been rock tests. From the results of about 125 of these tests, curves have been drawn illustrating the relation between compressive strength and toughness. The curves indicate that for high toughness the compressive strength is also invariably high. As in the case above, the compression may be high or low, when the toughness is low. Thus, if a hard rock with high resistance to wear and compressive strength is desired, it would be only necessary to require that it show high toughness; but with rocks low in toughness, all degrees of hardness, resistance to wear, and compressive strength could be expected.

Recommendations of rocks

Recommendations are based on the results of the tests and to some extent upon the variety of the rock itself, the type of road to be constructed and the amount of traffic it has to support.

A heavy traffic road for water-bound construction demands that the stone be hard and tough, with a high resistance to wear, and that it have a good cementing value. This same material, however, might be too hard for a lighter-traveled road, as the amount of material worn off by traffic would be insufficient to supply the powder needed as a binder to replace that carried away by wind and water, and the road would soon ravel. A light traffic road requires a softer rock. Material suitable for light traffic roads is abundant in Texas, and it needs little persuasion to have road-builders use it, no matter what the class of traffic might be.

It is necessary that there be an understanding of what is meant by heavy, medium, and light traffic on country roads. In the discussion and tables, the following classification will be used:

A *heavy traffic* road is one upon which considerable heavy hauling is done, such as a main highway leading into a town or city; or a street in the suburbs of a town or city, not a business street.

A *medium traffic* road designates one having considerable traffic of a light nature mingled with some heavy-loaded travel, such as would be found on an ordinary country highway or main road, a considerable distance from town.

A *light traffic* highway is one having nothing but lightly loaded vehicles traveling upon it, such as carriages or light wagons; as, for instance, a park or private road.

Since modern traffic has a tendency to the motor-driven vehicle, the plain macadam road of a decade ago is giving place to those treated with a foreign binder. The properties of road materials are somewhat different according to the type of construction used. From the nature of the binder, a bituminous road is resilient in itself and therefore the rock need not be one of high toughness nor cementing value. The resistance to wear will be the best index of its quality when used in this type of road. As a general rule, the rocks recommended for a certain class of traffic in plain macadam construction may be used with satisfaction on roads having a heavier class of traffic, if used in bituminous construction. That is, a limestone which is recommended for medium traffic in water-bound construction, would be satisfactory for heavy traffic in a bituminous road, provided the toughness was as high as 8, or over.

A rock which is too soft even for ordinary bituminous methods could be used with a bituminous matt wearing surface, so that the rocks would only support the weight of the traffic and receive very little wear.

Types of road-building rocks in Texas

This will include about 90 per cent. of limestones, which are very satisfactory as a type, but vary greatly as to their qualities. Their characteristics are good cementing value, but lack of toughness. In such case, larger size stones should be used. When the stones show a high resistance to wear and hardness, they are very satisfactory. Most limestones, however, do not possess this property, and under such conditions it may be advisable to use gravel or some other material. Limestones lend themselves to bituminous construction on account of their rough fracture and absorption, which is a good property.

Dolomites have practically the same properties as the limestones, except that their cementing values run somewhat lower, and their weight is usually about 5 per cent. greater.

Granites are hard, with high resistance to wear, but little toughness or cementing value. They are, therefore, satisfactory only in bituminous construction or as a foundation course in water-bound macadam roads. They lend themselves well to bituminous construction on account of the granular fracture. Their usual high degree of hardness gives a road a permanent character. Granites in Texas are of a high quality, but can be found only locally in such places as the Llano-Burnet country, or in scattered localities beyond the Pecos River.

Gneiss, schist, and slate are of considerable importance. They occur in greater abundance than granite, in the Llano-Burnet country, but are less well known. A hard gneiss is satisfactory as a material for bituminous construction, as the bitumen adheres to the stones.

Sandstones are of little use in water-bound macadam construction, as they lack binding properties. When not badly weathered, they are hard, and tough, and are very satisfactory for bituminous roads. If used in plain macadam, they should be surface-treated with a light oil.

Marbles, quartzites, and to a less degree, flints, are of rare occurrence in this State. They are too hard to crush economically, and should only be used as foundation.

Trap rock is undoubtedly the best material for water-bound macadam construction. It is hard, tough, and has, usually, a high resistance to wear and good cementing value. Trap rocks are those basalts and diabases which occur as sills, laccolites and dikes. They have a characteristic close-grained structure, and mostly a gray or black color. They are hard, being very satisfactory for heavy traffic plain macadam roads. The weathered varieties are softer and have a higher cementing value, recommending them for medium traffic. In bituminous construction they give very good results, or as an aggregate for concrete roads. Little of this rock is found in the central and eastern part of Texas, the principal deposits being in Uvalde county, and at Pilot Knob, in Travis county. West of the Pecos such rock is abundant

The soft chalky limestone, in which Texas abounds, is often used as a road material because of its convenience. It is worthless for this purpose, even for the lightest kind of traffic or with bituminous surface. It is quite satisfactory as a material for a sub-grade when well rolled into the soil, but it must be kept dry at all times.

The testing of road gravels

It is presumed that the sample of gravel to be tested is a good average of the material to be used. The material for the sample should be taken from a number of places in the pit, be mixed all together, and about 25 pounds of this taken to be used as the test sample

The testing of gravels is divided into three parts: (1) the grading test; (2) the cementation test; (3) the identification of the material. Besides these, the voids determination is sometimes made.

The grading test

In order to reduce the sample to a size small enough to be sieved, it is well mixed and quartered, to get about 2,000 grams for the sizing test. The remaining portion of the original sample is retained for the cementation test and also for a permanent sample to be filed with the recommendations

Before the sizing test or mechanical analysis is made, the gravel is washed in order to remove the clay. To do this the gravel, which has been dried at 100 deg. C., is agitated in a shallow pan containing water, for 15 seconds, and allowed to settle for 15 more, when the water with the clay held in suspension is poured off. This is repeated until the water remains comparatively clear after stirring. The washed gravel is dried and weighed again, so that the difference in weight is the clay and very fine silt. This very fine material will all pass the No. 200 sieve, which means that the particles are less than 1-350 of an inch in diameter, and represents the binder in the gravel.

The washed material is then run through both the stone and sand sieves. The stone sieves are eight in number, made of plates with round openings corresponding to the following diameters: 2-inch, 1½-inch, 1¼-inch, 1-inch, ¾-inch, ½-inch, ¼-inch, and ⅛-inch.

While it is customary among the concrete men to consider material below the ¼-inch sieve as sand, for the purpose of road gravels, the material passing the ⅛-inch sieve is called sand, and is run through the wire sand sieves on the Tyler system, from No. 10 to No. 200, including the following sieves: No. 10, No. 20, No. 28, No. 35, No. 48, No. 65, No. 100, and No. 200. Such material as passes the No. 200 sieve is a very fine sand, which failed to go off in the washing test. It is always a very small amount, seldom more than 1 per cent, and this is added to the clay.

The machine shown in Plate X is the mechanical sieving device, used in making the mechanical analysis. The sieves are meshed as shown and the sample run through all of them at one shaking by the vibrator.

The cementation test

The cementation test is made on gravels by the same methods as in a rock sample, except that three determinations are made on one gravel sample: (1) on the material as it comes from the pit; (2) on the stones failing to pass the ⅛-inch sieve; (3) on the sand and clay passing the ⅛-inch sieve.

With a gravel, as with rock, the dust worn off from the stones often supplies a binder, especially in a limestone gravel. To ascertain the quality of this binder, a cementation test is made on the larger fragments of the gravel. By a cementing value determination on the material under ⅛-inch in size, the relative binding properties of the clay or very fine material are brought out, while a determination on the sample as run in the pit gives an index of what may be expected of the road after it has begun to wear. This latter value will fall between the first two.

It is essential that the material under ⅛-inch should show a high cementing value, as this is the material which holds the larger stones together and forms the impervious crust essential to a permanent road. The cementing value on this should range over 100, which is excellent, but if it contains high cementing clay, its cementing value goes to a much higher figure than this.

Identification of material

An examination of the material is made in the laboratory to ascertain the composition of the gravel, the hardness and kind of rock from which it was derived, and also the nature of the fine material, all of which aids in the judgment of the value of the material for road-building.

Recommendations of gravel

In judging a gravel from the results of the tests, due consideration is given to the fact that it is very difficult to get a small sample which would exactly represent the pit, and figures are considered only in a relative sense.

In recommending a gravel as being satisfactory, it is considered that the stones themselves shall be hard and fairly well graded in size, with enough sand—and only enough—to fill the voids. Experience seems to indicate that this amount should be about 30 per cent. of the sample. In order to carry this over the dry spells, it is necessary that about one-third of the sand be replaced by clay or 10 per cent. of the entire sample. This is not enough to become muddy in wet weather, and just enough to keep the road well bonded, over an ordinary dry spell.

The kind of material making up the gravel has considerable influence upon the clay question. The above discussion is primarily for quartz, flint or granite gravels, but as a large proportion of Texas gravels is of limestone origin, they must be considered also. The stones themselves will supply the bond so that little clay is necessary and, in fact, very little is found in this type of material. The fine material is usually of a calcareous nature and proves a satisfactory binder. Furthermore, as limestone itself is a comparatively soft material, it is continually supplying fine material, so that the initial amount need not be more than 7 per cent. of the sample. Some limestone gravels are too soft for road construction and should not be used, except under very light traffic or as a foundation course with a wearing surface of better material. From the nature of the mode of formation of gravels, they should have a high resistance to wear, but if the gravel is deposited near the source of the rock from which it is derived, it need not be hard, as it has little chance to wear before being deposited.

In considering further the grading of a road gravel, it would be incorrect to say that only those gravels having 30 per cent. sand are satisfactory. These, however, have given the best service. Good roads are in service where a much higher sand and clay content than this has been used, but such gravel requires more maintenance and does not last as long. Gravels are tested that have over 75 per cent. of their material below the ¼-inch sieve, but they are really sands, and can only be recommended as a sand-clay construction material.

Gravels lacking clay with the exception of limestone gravels, give fairly good results for the first year, but after that they are very dusty unless there is considerable underground water present.

In bituminous construction, gravel roads lend themselves best to surface treatment of asphaltic oils or tars applied hot or cold. It is necessary, however, that the road be well packed and swept clean before applying the bituminous binder.

The testing of other road materials

This includes granite and wood blocks, brick, concrete, and bituminous materials. Tests of these are valuable in ascertaining for the purchaser just what grade of material he is getting. They enable him to buy his road on definite specifications, with the assurance that they will be complied with.

Granite blocks

Granite blocks are tested for their properties as to hardness, toughness, and resistance to wear in the same manner as rocks for macadam roads. A compression test is also made on a 2-inch cube cut from the block. The greatest stress is placed on the toughness test, as a tough granite will be hard and have a high resistance to wear. In fact, this is the only test demanded by many specifications, while others include the compression test of 18,000 or 20,000 pounds per square inch. The American Society of Municipal Improvements recommended a toughness of 9 as a minimum for granite, but this is a rather low figure. The stone itself should be even-grained, without disintegration, or an overabundance of mica or feldspar, and the blocks should run in uniform size.

Very few granite block pavements have been laid in Texas, due probably to the fact that the traffic conditions did not warrant the cost. Excellent granite can be had in Texas for this purpose and a larger field should be developed for its use.

Wood blocks

Wood blocks are usually specified as to size, variety of wood and kind and amount of filler used, and are tested for these properties. The common practice is to use a filler of a creosote oil of a specific gravity of about 1.10 at the rate of about 16 to 20 pounds per cubic foot, varying according to the variety of wood and the traffic. The variety of wood is usually limited to yellow pine, Norway pine, Douglas fir, and tamarack, of even growth and free from knotholes.

The only test considered necessary is to test the filler to see that it passes specifications, which are usually those of the Association of Standardization of Paving Materials. Absorption of the block is sometimes determined, but it varies to such an extent that it is of little value. Wood block pavements are confined to heavy traffic streets and have no place in road work, on account of their high cost.

Paving brick

Paving bricks have taken a big stride into public favor in the last few years, from many causes; one of which is the good grade of bricks the manufacturers are turning out.

In testing brick, the sample should be a representative one and not less than 10 brick for each 10,000 to be used should be tested, in order to secure a good average of the shipment. The sample, however, should not include any brick that would be culled out upon visual inspection.

The tests on brick include hardness and toughness tests, made on a core drilled from the brick, as is done in the rock test. The cross-bending test is also made as an index to the toughness of the brick. It is made by applying a load by means of a knife edge in the center of the brick which rests on two other knife edges, 7 inches apart. The modulus of rupture is calculated from the breaking load. A compression test is also made on a 2-inch cube cut from two blocks. Besides these, the absorption and specific gravity tests are made.

These tests are of little value themselves, but on account of the correlation of data of a considerable number of blocks known to be satisfactory, a good estimate of their value can be given.

The most meritorious test, however, on paving brick is the rattler test, which is described in the 1913 Proceedings of the American Society for Testing Materials. It consists of revolving 10 blocks in a cast-iron barrel, 28½ inches in diameter and 20 inches long, inside. The machine is also charged with an abrasive agent, consisting of 10 cast-iron spheres, 3¾ inches in diameter and 250 smaller ones, 1⅞ inch in diameter. It is revolved for 1,800 revolutions at 30 r. p. m.

The loss in weight is reported in per cent. and should not run above 24, for heavy traffic street work

The manufacture of paving brick in the State is very limited; in fact, only one company now in operation is known to the Bureau, this being located at Thurber, Erath County. The tests on some brick from this place show them to be of excellent quality.

Concrete materials

The concrete pavement has of late taken a permanent place among the modern highways, and when well constructed with good materials, fulfills expectation.

The testing of concrete for road work is limited to ascertaining the properties of the aggregate used. The cement is tested according to the methods of the American Society of Testing Materials, and is required to pass these specifications.

The sand used in the concrete is made into 1:3 briquettes, using the cement, and coincident with 1:3 tensile briquettes of standard Ottawa sand; and at the same time, 2-inch cubes are made of the same mix. These specimens are required to show at least the strength in tension and compression of the standard sand specimens. The grading and composition of the sand is ascertained. Quartz or flint sands are the best, but a hard limestone is quite satisfactory. If the sieving test shows more than three per cent. silt below the No. 200 sieve, the sand should not be used unless washed.

The coarse aggregate should be a hard material that will resist the wear, such as a flint or quartz gravel, well graded between ¼-inch and 1½ inches. Hard limestone gravels give good results. If the stones in a limestone gravel can be readily scratched with a knife, the gravel is too soft for use. Crushed trap rock, granite, hard sandstone and limestone, are very good aggregates when well graded between ¼-inch and 1¼ inches The stone itself should have at least a toughness of 7. The coarse aggregate should be free from silt or fine dust, also usually limited to 3 per cent., provided it does not coat the stone itself.

A sieving analysis is made on the concrete aggregate to ascertain its grading. The weight per cubic foot of the material, and the voids determination is usually made. Compression cylinders 6 inches in diameter are made, using definite proportions and a standard cement, and are tested at the end of 28 days so as to compare with the average of a good concrete. As the time element is so great in this test, it is made more as a check on the other tests, and is reported as such. An attempt is being made in the laboratory to develop a test on concrete aggregates for road work so that the merits of the material can be determined in a short time.

Bituminous materials

This subject is such a broad one that it will not be considered in this discussion, further than to emphasize the necessity of buying these materials on specifications, and of seeing that these are complied with. For each type of bituminous construction, a different oil is necessary, the requirements being modified by the method of application and the results desired. The tests demanded may all be included under the head of physical testing, although most of them are made on such equipment as is found in a chemical laboratory. The Bureau through its chemical laboratory is in position to make practically all the tests demanded on bituminous materials, however, the field in this line of work at the present time is practically confined to city streets, but it is believed that the time is not far off when bituminous trunk lines will be a necessity.

CHAPTER III

GENERAL DISTRIBUTION OF ROAD MATERIALS IN TEXAS

The characteristic material in the coast country of Texas is shell and shell alone, so that little choice exists for the road-building material. Any type of road other than shell would entail a very great expense. A bituminous surface, however, relieves a number of objections to the shell road, and proves to be an economical method of obtaining a good road in that part of the state where nothing but shell is available. Further inland, sand-clay roads prove more economical where good sand and clay can be obtained; but unless the materials are of good quality, the road will never be satisfactory, and it would be better to bring in shell or gravel from the nearest point.

About 150 miles from the coast, the great gravel-bearing area commences. Gravel may be found almost anywhere in the south-central, north-central, and north-east part of the state. This very general distribution makes it inevitable that gravel roads should become our most common type of construction. This is very fortunate, as a gravel road gives greater satisfaction for the initial investment than any other type, especially when maintenance is rather meager. At this period of Texas road-building, it is necessary that a large mileage of improved roads be obtained with a comparatively small investment. When the demand for a highly improved road is great enough, it is believed that the need will be filled by the concrete road; in which case, gravel will still play the leading rôle. At almost any place along the line of the M., K. & T. railroad, except near Houston, there are to be found excellent limestone gravels. In northeast Texas, in a great circle of above 75 miles radius, with Smith County as its center, iron ore is an ingredient in the gravels. When composed of hard stones, this gravel is even superior to the limestone gravels for road-building.

In some parts of west Texas, and in the Panhandle, road materials are scarce, but they are unnecessary, as excellent roads can be built in this region from the surface earth, and will remain in good condition with little maintenance.

In southwest Texas, in Brewster, Presidio, El Paso, and Jeff Davis counties, large deposits of satisfactory rock material and gravel can be found; but as the country is sparsely settled, the need of the higher type of improved roads is not yet felt. Granite, trap rocks and limestone can be found in this mountainous country.

In central Texas, a belt of fairly hard limestones and dolomites from Jack County south to Llano County is found. In Llano, Burnet, and Mason counties, a hard granite and also some good granite gravels are found. At Pilot Knob in Travis County, and Knippa in Uvalde County, an excellent trap rock is obtainable, which is undoubtedly the best stone in Texas for road-building. A natural rock-asphalt is found at Cline, in Uvalde County, and when fluxed with some oil asphalt, it seems to prove very satisfactory for city streets.

A general geographic distribution of the materials already tested and included in the tables is shown in Plate XIX. The State of Texas is of such great size that a complete road materials survey would involve a lifetime and still be incomplete.

CHAPTER IV

NOTES ON TESTED ROAD MATERIALS, BY COUNTIES

Atascosa County

One sandstone conglomerate was tested, which showed very poor wearing qualities and toughness, rendering its high hardness of no value.

Bastrop County

Three gravels from Smithville were tested, all of which showed excellent cementing value, supplied by a red oxide of iron clay which they contained. These gravels stand well in the bank and make very good roads. They should do well, also, as a wearing course for a road with a foundation of poorer gravel. Plate XI gives a view of the gravel pit of M. E. Maney, Smithville. This pit has a face of 35 feet.

Bell County

Two limestone gravels from Temple showed excellent cementing value, recommending them for binder course. Number 2271 should also make a satisfactory one-course road. Number 2252 shows poor grading of the stones, lacking the larger sizes to a considerable degree. Three tests made by the U. S. Office of Public Roads are also included for comparison.

Bexar County

Most of the samples tested in this county were limestone gravels, all of which showed good binding properties. Two samples contained flint stones; and in No. 2136 the large stones above two inches in size were screened out before the analysis was made, as it is necessary to screen and crush these stones before the gravel can be used with satisfaction on a road. Those gravels not recommended contained too much fine material to render a road satisfactory for any length of time.

The tests made on the limestone reported in the table were

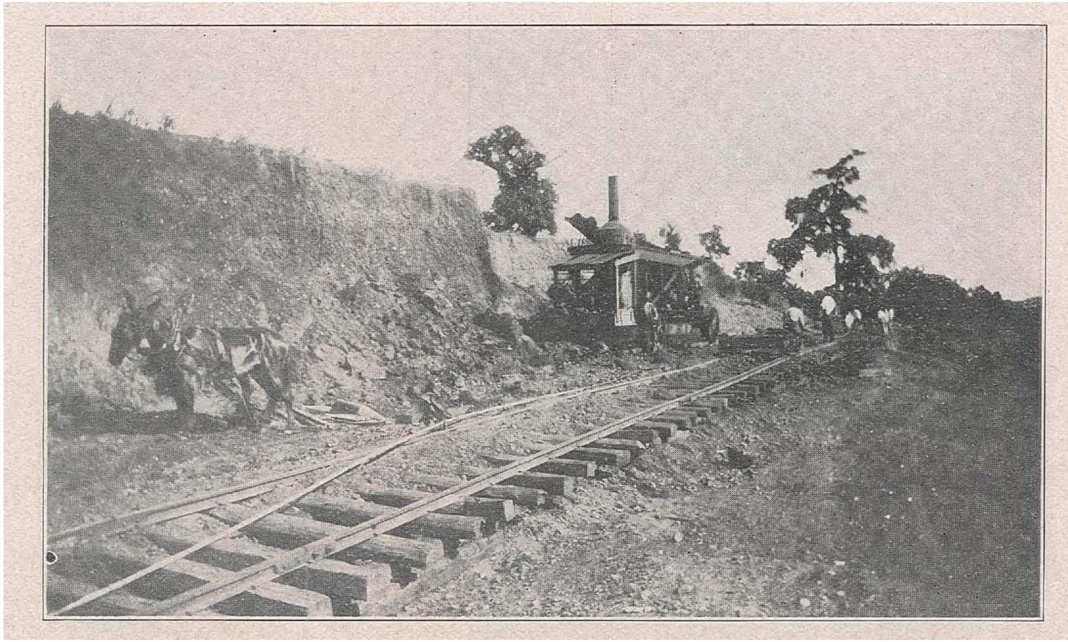

Plate 11. Gravel Pit of M. E. Maney, Smithville, Bastrop County. Exposure 35 feet.

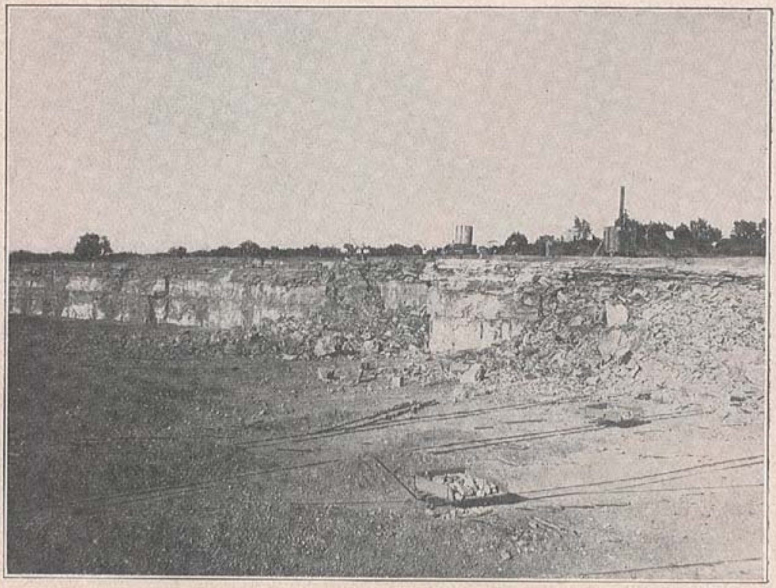

Plate 12. Limestone Quarry, Tiffin Crushed Stone Co., Ranger, Eastland County, Limestone No. 2231.

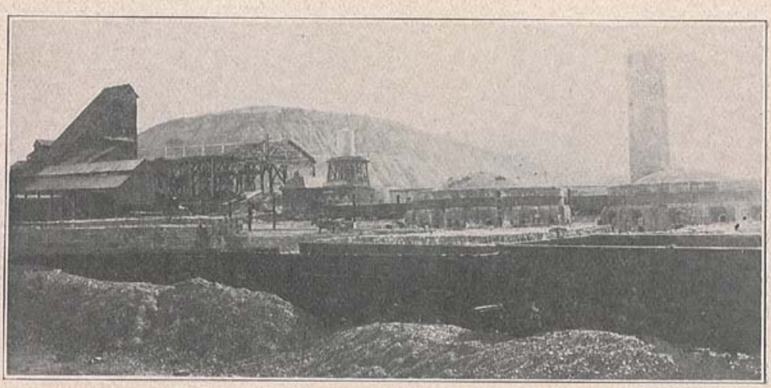

Plate 13. Plant of Thurber Brick Co., Thurber, Erath County.

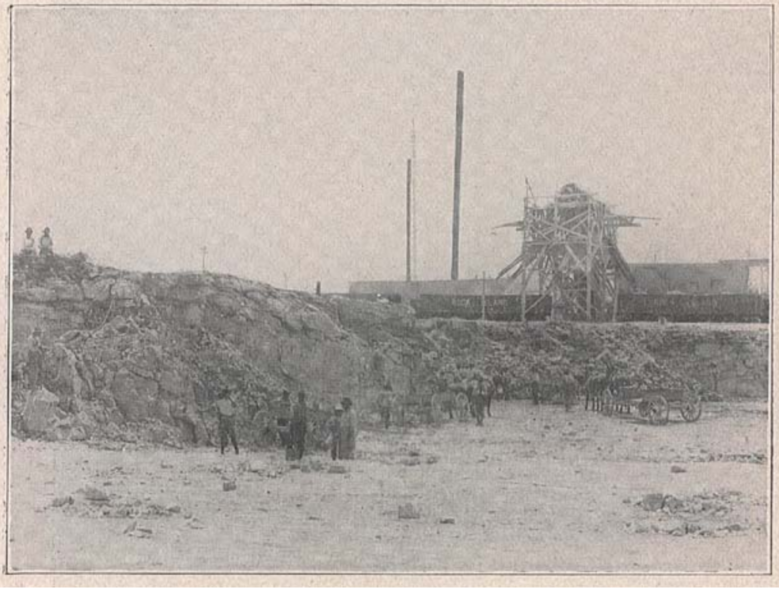

Plate 14. Limestone Quarry of Risley Bros., Jacksboro, Jack County.

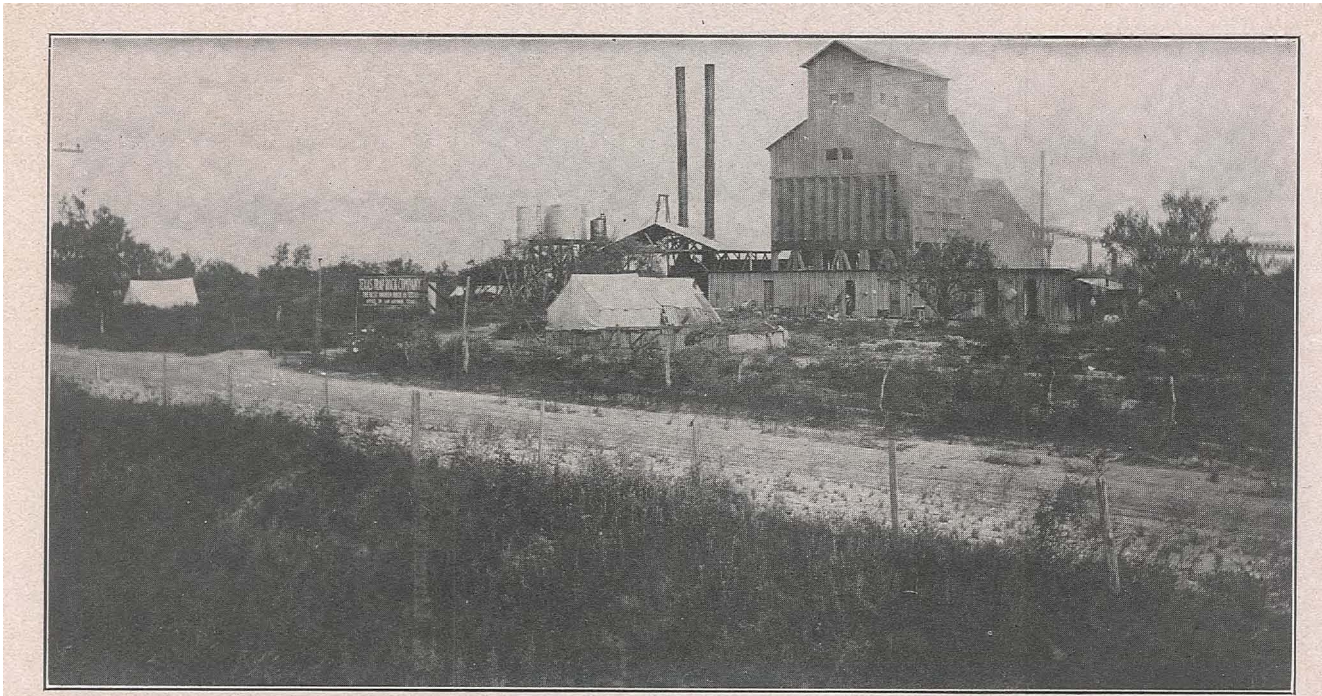

Plate 15. Works of Texas Trap Rock Co., Knippa, Uvalde County. Office of Public Roads Laboratory No. 7129.

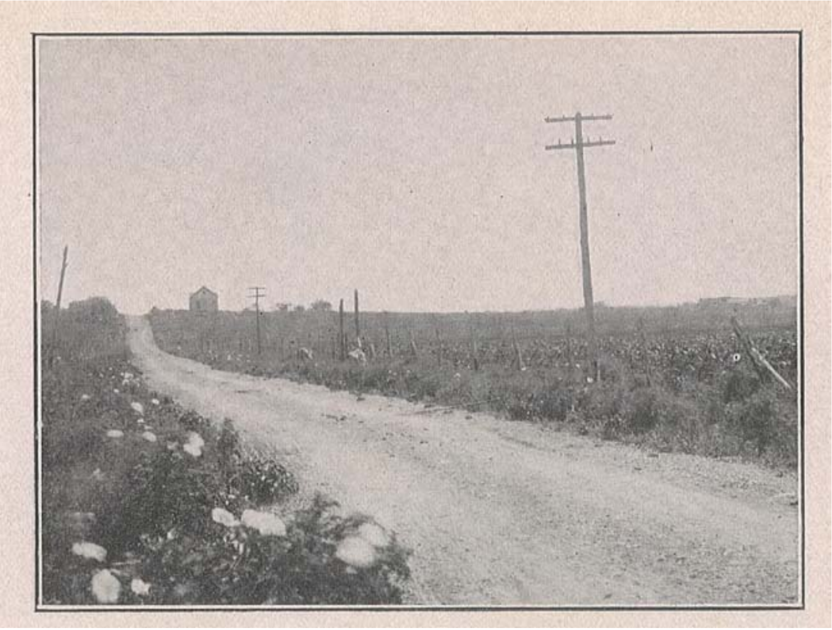

Plate 16. Gravel Road Between Montopolis Bridge and Pilot Knob, About 5 Miles from Austin, Travis County. Built with Gravel No. 1856.

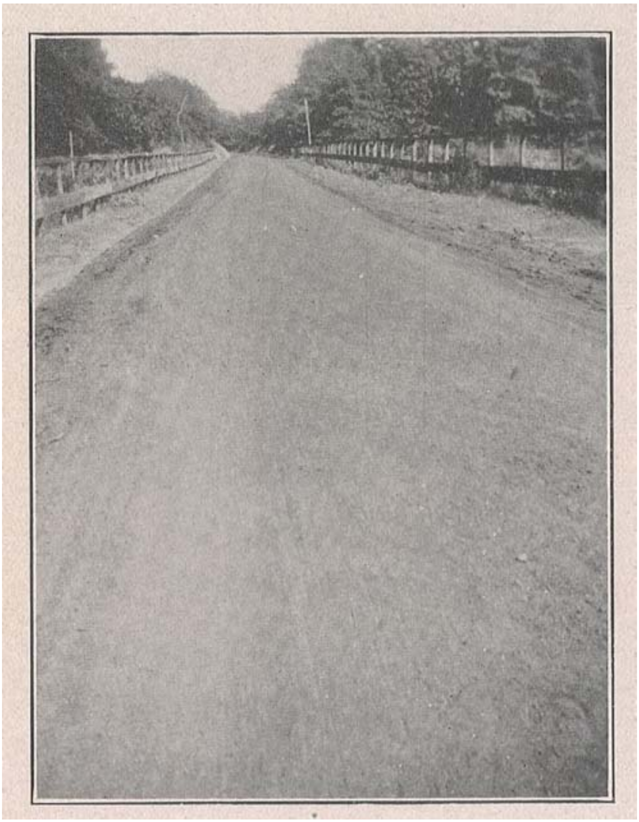

Plate 17. Iron Gravel Road Near Palestine, Anderson County. Built with Gravel No. 2659.

Plate 18. Iron Gravel Road at Henderson, Rusk County. Built with Gravel No. 2654.

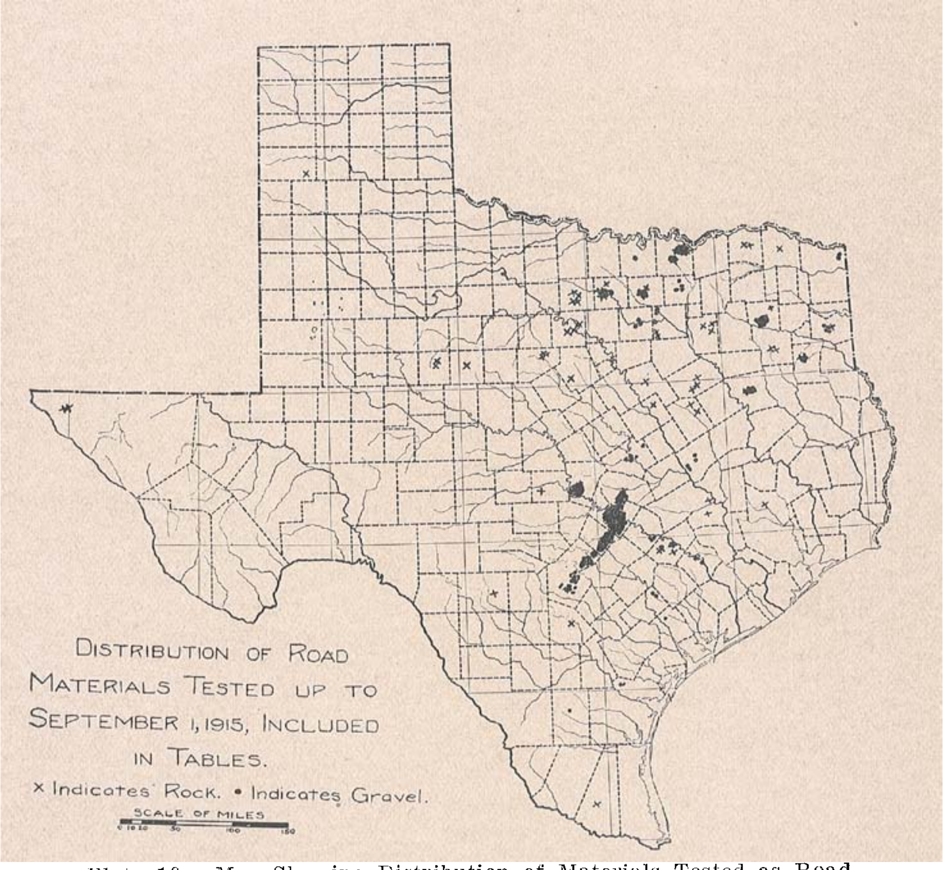

Plate 19. Map Showing Distribution of Materials Tested as Road Metal in Texas.

not full enough to make possible an accurate judgment of the material. It is believed, however, that most of them would show up rather soft.

Bowie County

One sand and one gravel sample from Texarkana were tested for concrete aggregate, both proving to be excellent concrete material. Compression cylinders made from a 1:2:4 mix and stored in water, failed to break at 3,700 lbs. pressure per square inch, at 28 days, which is the capacity of the laboratory machine.

Burnet County

This county is one of the most fortunate in good road materials, especially in rock; having limestone, dolomite, and granite, as well as some granite gravels. A considerable number of these materials have been tested, most of them being good for bituminous construction; particularly the dolomites. These latter are somewhat heavier than limestones, as about 40 per cent. of the carbonate of lime is replaced by carbonate of magnesia which has a heavier specific gravity than calcium carbonate. From the table it will be seen that none of the rock is unsuitable for road material, and about 80 per cent. is suitable for medium traffic if used with a bituminous binder. Those recommended only for light traffic should be used with a thin bituminous matt if used on heavier traffic roads; otherwise they will not prove satisfactory. In not one sample tested does the crushing strength fall below 10,000 pounds per square inch, which is the minimum allowed for railroad ballast, or concrete aggregate.

The four granite gravels have considerable red oxide of iron clay as binder, but all the stones, although hard, are small. This type of gravel is an excellent one for a top course and gives satisfactory results in one-course construction after it becomes packed, but tends to soften when wet. On account of the absence of large stones it is considered a sand-clay and is recommended as such. If well drained, a gravel of this type should be very satisfactory.

Collin County

The gravels tested by the U. S. Office of Public Roads were found to be fairly satisfactory, while the one tested by the Bureau contained too much sand and fine material of a calcareous nature to be satisfactory.

Colorado County

The two gravels tested in Washington, of a cherty nature, were recommended as fairly satisfactory, their cementing value being somewhat low.

Comal County

The characteristic rocks in this county are either the Edwards limestones or Austin chalk, both of which are soft and make poor road-building material. In fact, the Austin chalk is absolutely worthless. Only three rocks are hard enough to be used at all, so it is to the gravels that this county must look for local road materials. These latter all show very good binding properties and most of them are well graded, with limestone as the characteristic stone. Practically all of the gravels are recommended although the fine material varies considerably in amount. However, as this is all calcareous material, the fine matter will be constantly supplied from wear of the stones, its amount varying with the age of the road and the amount of traffic it receives. Roads having considerable motor traffic should be treated with asphaltic oils to prevent dust.

Cooke County

This county is represented by one limestone gravel only, which was tested by the Office of Public Roads and was recommended for light traffic only, as it was composed of rather soft material.

Dallas County

The two limestones tested from this county are too soft to be of any use whatever. The gravel samples tested as railroad ballast were found suitable, while the other two gravels were recommended for road work. The one tested by the Office of Public Roads, however, was recommended for very light traffic.

Deaf Smith County

Only one very soft limestone was tested. It could not be recommended on account of that quality.

Denton County

Two very satisfactory limestones were tested, which showed up well as material for railroad ballast; or concrete aggregate, if crushed to the correct size. The gravels as a rule contain some iron oxide material, which makes an excellent binder. Two of the gravels were found unsatisfactory.

DeWitt County

Both gravels tested in Washington were found to be unsatisfactory for road work.

Duval County

A quartz gravel from here is recommended for road building. Its hardness is a good quality.

Eastland County

The limestones from this county which have been tested are rather poor in quality from the road-building point of view, being only satisfactory for light traffic in waterbound macadam construction. However, if used with a bituminous binder, they could be employed in heavier traffic. The quarry of the Tiffin Crushed Stone Company at Ranger is shown in Plate XII.

El Paso County

The three syenites from this county show high hardness and a fair degree of toughness, with good cementing value. With the exception of the last one, they are very satisfactory.

Erath County

Some vertical fibre brick made at Thurber proves, under the tests, to be a high grade product in all respects. These brick are made by the plant of the Thurber Brick Company shown in Plate XIII. The limestone from this county is only recommended for light traffic, due to its very low resistance to wear.

Fayette County

Three limestones from O'Quinn proved, under test, unsatisfactory as road materials, showing a very low resistance to wear, and low toughness. Number 2091 showed high hardness, but the rock is not homogeneous and is generally soft, as shown by the French coefficient, so that it is not recommended. The quartz and flint gravel from this place does not contain any binder to recommend it for gravel road construction; but if screened through a one-fourth inch screen and mixed in proper proportions, it should make a good concrete aggregate. The sandstone, No. 1982, shows up well as a material for bituminous construction, railroad ballast, or concrete aggregate, if crushed to proper size. Number 1981 is too soft for any purpose.

Gillespie County

One marble from Cherry Springs, which was tested but not included in the tables, shows up fairly well. It is satisfactory for medium traffic bituminous construction, or as a foundation course in a waterbound macadam road.

Grayson County

The ferruginous sandstone from Denison shows qualities which fit it for bituminous construction, but it is not recommended for plain macadam roads because of its poor binding properties in practice. This rock has all the properties needed for a very good railroad ballast and concrete aggregate, having a compression strength of over 20,000 lbs. per square inch. The granite tested by the Office of Public Roads in Washington has a medium resistance to wear, and is very hard, which recommends it for bituminous construction; but granites as a type are unsatisfactory in waterbound construction, on account of their lack of mechanical bond in the grains. A number of limestones are also included in the table, most of them being satisfactory for some kind of traffic. The two limestone gravels are only recommended for very light traffic.

Guadalupe County

The gravel taken from the bed of Cibolo Creek should be crushed and used for concrete aggregate. Gravel No. 2138, from the north bank of this creek, is a satisfactory material for road construction.

Harrison County

A disintegrated sandstone gravel proved unsatisfactory under test, being soft and of rather poor binding properties. A ferruginous sandstone rock was found to be too soft to be of any use, as was also the case with some ferruginous sandstone conglomerates noted in the tables.

Hays County

The rock here is a continuation of the formations of Comal County, and a great similarity in the rocks is found, as should be expected; with the possible difference that those in this county are slightly better for road-building purposes. Several of these rocks can be used under medium traffic, and one can be used for railroad ballast. It will be noticed how much lower the average crushing strength of these limestones is, than those in Burnet County. Those not recommended in the table are worthless and should not be used under any consideration, as gravel would be much more economical.

A number of gravels have been tested, all of which are of limestone origin and have good binding properties. Several of them, however, are not recommended because of a poor quality of the stone composing them, or because of very poor grading; all of which is apparent from the results given in the table.

Hidalgo County

The one material tested from this county is an argillaceous limestone from one and one-half miles south of Monte Cristo. It should be satisfactory in a plain macadam road under light traffic, or under medium traffic in bituminous construction. Its crushing strength of 13,000 lbs. per square inch recommends it for railroad ballast or concrete aggregate, if crushed to correct size.

Jack County

The Jacksboro limestone tested for compression is the only stone examined from this county, as shown in the table. A well known quarry of this limestone is shown in Plate XIV, which is the property of the Risley Bros. at Jacksboro.

Karnes County

One caliche was tested, which proved to be worthless.

Kaufman County

All three of the limestones from this county have a low resistance to wear and are not especially good for road work.

Lamar County.

One sandstone tested in the Government laboratory showed zero hardness and very low resistance to wear, which renders it useless. A conglomerate tested fairly well, and could be used if something better was not available.

Limestone County

As might be expected from its name, two limestones represent this county. They are rather soft, and are recommended only for light or very light traffic. Number 8591, from the Springfield Rock Company, is the better of the two.

Llano County

A granite from Tom Norton's quarry gave a crushing strength of 20,300 pounds per square inch, a hardness of 18.8, and toughness of 15; which designates it as being an excellent material for granite block pavements. Some paving of this block was laid in Houston about seven years ago, and also in front of the Dallas postoffice at Dallas; and is said to be in very good condition in both places. Burnet and Llano granites are equally as good as, if not superior to, any that might be shipped in to the State.

The gabbro from this county shows high compressive strength, of over 26,000 lbs. per square inch, and is hard and tough, recommending itself for bituminous construction under heavy traffic, or as a foundation course.

Montgomery, McLennan, Navarro, Nolan Counties.

Limestones tested from these counties are shown in the tables.

Palo Pinto County

Three limestones from this county recommend themselves for light traffic in waterbound construction, or medium traffic if a bituminous binder is used.

Pecos County

Three sands from the vicinity of Fort Stockton were tested as concrete sands. Number 2316 is the best of the three, the others being of doubtful value for this purpose.

Red River County

The only test made on material from this county was on a very soft limestone, which proved useless for any road-building purpose.

Robertson County

The gravels here were not recommended by the Government engineers because they contained too much fine material under one-eighth inch in size. Their binding properties are good and might be used to supply the binder in coarser material.

Rusk County

This county lies in the ferruginous sandstone region and all materials from there are of that type. The ferruginous sandstone tested showed lack of toughness, and therefore could only be used in bituminous construction. The conglomerates were not satisfactory, as they are too soft. A good iron gravel road is shown in Plate XVIII, at Henderson. This had been down one year when picture was taken. Laboratory No. 2654 gives the results of the tests on this material.

San Patricio County

Two soft limestone gravels from Mathis were tested for railroad ballast, but contained too much fine material to be satisfactory.

Smith County

The Office of Public Roads tested two ferruginous sandstones which would be satisfactory for bituminous construction under medium or light traffic. Only one, however, is recommended for waterbound construction, its cementing value being excellent.

Tarrant County

One gravel tested for concrete aggregate showed up well.

Taylor County

The one limestone tested is recommended for medium traffic roads, as it is fairly hard and resistant to wear.

Travis County

More work has been done in this county than any other, the tests covering 120 samples, of which one-half are gravels. The predominating rock is a rather soft limestone, most of which is only satisfactory for light traffic in plain macadam roads. However, a majority of it might be used in bituminous construction under medium traffic. Low toughness is characteristic of these limestones, as can be seen on the table, and the coefficient of wear is none too good; but a number of quite satisfactory rocks can be found. This county is particularly fortunate in having a deposit of a nephelite basalt or trap rock which is an excellent road-building stone especially for heavy traffic. This is located at Pilot Knob, somewhat distant from transportation facilities, but it is hoped that in the near future some of this material can be located within economical reach of a good shipping point. One flint tested from the Bee Cave road, 5 miles from Austin, shows up well for a foundation course, but its economy for this purpose is doubted. Flint possesses no binding properties and should not be used as a top course, nor is it satisfactory in bituminous construction.

The characteristic of the gravels, as with the rocks, in this county, is that they are limestone, although a number of quartz gravels are found. These latter are usually composed of small pebbles and clay and are recommended as a binder course. When used on a one-course road, they become soft in wet weather and require considerable maintenance. For this reason they are not recommended. One of the limestone gravel roads is shown in Plate XVI, which lies between the Montopolis Bridge and Pilot Knob, built with gravel No. 1856.

The soft chalky limestones which underlie the greater part of Travis County are absolutely worthless and should never be used.

Uvalde County

Undoubtedly the best stone handled commercially for heavy traffic roads is the trap rock at Knippa. Like the Travis County deposit, this is a nephelite basalt of high resistance to wear and very high compressive strength. It should make an excellent railroad ballast, although rather costly for this purpose. If crushed to give proper grading, it makes an excellent concrete aggregate. Plate XV shows the plant operated by the Texas Trap Rock Co., producers of this stone.

At Cline, a deposit of rock asphalt is being worked for street paving. It runs from 12 to 16 per cent. in asphalt in a fossiliferous limestone, and is used by laying it hot, fluxed with an asphaltic oil. From reports on this material, it seems to prove very satisfactory.

Victoria County

The gravels in the table are free from clay and should prove satisfactory as a concrete aggregate, or in a road surface treated with bituminous material.

Williamson County

All the material tested from this county is either limestone or limestone gravel, both of which run about the general average for such materials.

Wise County

The limestones from this county are mostly satisfactory, although some only lend themselves to light traffic.

Wood County

This county is also in the ferruginous sandstone region and most of the material tested is unsatisfactory. There is one gravel which is very good.

APPENDIX

Results of Tests

Following is a table of all the road materials of Texas that have been tested in this laboratory and the Office of Public Roads Laboratory to September 1, 1915, with their locations, arranged in counties. The best material is placed at the top of the list, the poorest at the bottom, and the intermediate ones varying according to their worth between these extremes. Furthermore, in making the recommendations, the available materials are taken into consideration, so that a doubtful stone in Burnet County, where considerable good road material can be found, might be recommended for use in Comal County, where the best material obtainable is none too good. This is somewhat on the principle which prompts a person in one locality to say that a certain road is in excellent condition because it is the best they have; while a person from another locality, where good roads predominate, would have little enthusiasm for their "excellent" road.

The table for gravels is arranged, like that for the rocks, according to counties, with the best material heading the table, and graded from this to the poorest at the bottom.

Those samples marked with an asterisk have been tested by the Office of Public Roads laboratory at Washington, and their recommendations are used wherever they could be obtained; otherwise they were added by the writer.

The writer desires to express his appreciation of the services of E. L. Porch and Geo. C. Parkinson for their services in the work necessary for the data in this bulletin.

TESTS ON GRAVELS, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL

Laboratory No.	Characteristic Material Composing Gravel	Mechanical Analysis: Percent Retained on 2-inch sieve	1-inch sieve	⅛-inch sieve	No. 48 sieve	No. 200 sieve	Percent passing No. 200 sieve	Cementing Value: Material Above ⅛-inch	Below ⅛-inch	As received	Recommendations
	ANDERSON COUNTY										
2659	Sandstone	0	3	58	83	90	10	Excell.	Excell.	Excell.	Fair material. See Plate XVII.
2656	Sandstone	0	1	33	83	97	3	------	Excell.	----------	Good binder course.
2657	Sandstone	0	1	35	41	66	34	------	Excell.	Excell.	Good sand-clay road.
2658	Sandstone	0	0	36	59	81	19	------	Excell.	Excell.	Good sand-clay road.
	BASTROP COUNTY										
2166	Quartzite and flint	0	21	52	85	88	12	Fair	Excell.	Excell.	Good material.
2149	Quartzite and flint	0	9	46	87	89	11	Fair	Excell.	Excell.	Good binder course.
2167	Quartzite and flint	0	5	42	89	92	8	Fair	Excell.	Excell.	Good binder course.
	BELL COUNTY										
2271	Limestone	0	15	75	83	85	15	Excell.	Excell.	Excell.	Good material.
*6681	Limestone and quartz	0	9	74	85	88	12	Good	--------	Excell.	Light traffic roads.
*6679	Limestone and quartz	0	12	68	93	96	4	Good	Excell.	Excell.	
2252	Limestone and quartz	0	6	62	81	83	17	Good	Excell.	Excell.	
*6680	Limestone and quartz	0	7	54	75	79	21	Excell.	Excell.	Excell.	
	BEXAR COUNTY										
2002	Limestone	11	27	79	92	94	6	Good	Excell.	Good	Good road material.
2135	Limestone	0	27	69	85	87	13	Good	Good	Good	Good road material.
2139	Limestone	15	56	68	81	84	16	Good	Excell.	Excell.	Satisfactory.
2136	Flint and clay	0	33	66	78	81	19	Good	Excell.	Excell.	Crush large stones.
2134	Flint and limestone	0	15	82	96	96	4	Good	Excell.	Good	Fair road material.
2137	Limestone	7	25	60	86	91	9	Good	Good	Good	Very light traffic.
2003	Limestone	0	0	55	90	93	7	Fair	Good	Fair	
2133	Limestone	9	21	57	66	73	27	Good	Excell.	Excell.	
2132	Limestone	0	18	57	72	78	22	Good	Excell.	Good	
	BOWIE COUNTY										
2345	Flint, quartz, chert	4	42	100	--------	--------	--------	------	--------	----------	Very good concrete aggregate.
2346	Quartz sand	0	0	7	88	100	--------	------	--------	----------	Very good concrete sand.

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

BURNET COUNTY

2173	Granite and clay	0	0	41	77	83	17	Excell.	Excell.	Excell.	Good binder course.
2172	Granite and clay	0	0	52	82	87	13	Good	Excell.	Excell.	Good binder course.
2171	Granite and clay	0	2	52	80	85	15	Good	Excell.	Excell.	Good binder course.
2174	Granite and clay	0	0	56	89	94	6	Good	Excell.	Excell.	Good binder course.

COLLIN COUNTY

*5901	Limestone and sandstone	0	4	70	93	-------	-------	Excell.	Excell.	Excell.	Fairly satisfactory.
*5900	Limestone and sandstone	0	3	63	90	-------	-------	Excell.	Excell.	Excell.	Fairly satisfactory.
2645	Limestone and flint	0	16	45	73	83	17	Excell.	Excell.	Excell.	

COLORADO COUNTY

*6754	Chert and quartz	-------	51	79	89	92	8	Poor	Good	Good	Fairly satisfactory.
*6753	Chert and quartz	-------	24	62	83	90	10	Poor	Good	Fair	Fairly satisfactory.

COMAL COUNTY

2098	Limestone	0	20	79	90	92	8	Good	Good	Good	Good road material.
2097	Limestone	1	13	75	91	94	6	Fair	Excell.	Good	Satisfactory.
2083	Limestone	5	14	74	90	93	7	Good	Good	Good	Satisfactory.
2084	Limestone	7	29	83	90	93	7	Excell.	Good	Good	Satisfactory.
2068	Limestone	0	26	83	89	91	9	Fair	Excell.	Good	Satisfactory.
2079	Limestone and flint	7	22	82	91	97	3	Good	Good	Good	Satisfactory.
2095	Limestone and flint	13	45	71	83	85	15	Good	Excell.	Excell.	Satisfactory.
2089	Limestone	5	21	60	87	91	9	Good	Good	Good	Satisfactory.
2087	Flint and limestone	0	29	77	86	87	13	Fair	Excell.	Excell.	Satisfactory.
2088	Limestone	11	33	66	82	83	17	Fair	Excell.	Good	Satisfactory.
2082	Limestone, chert, shells	10	31	71	86	88	12	Good	Excell.	Good	Satisfactory.
2094	Flint and chert	17	40	78	85	87	13	Fair	Excell.	Good	Good if large stones are removed.
2093	Flint and clay	20	57	86	89	90	10	Poor	Excell.	Excell.	Good if large stones are removed.
2096	Limestone	30	41	83	88	89	11	Excell.	Excell.	Good	Good if large stones are removed.
2066	Limestone and flint	3	21	73	82	84	16	Good	Excell.	Excell.	Satisfactory.
2081	Limestone	7	13	63	80	85	15	Good	Excell.	Good	Light traffic roads.
2080	Limestone	5	26	74	83	84	16	Excell.	Excell.	Excell.	Light traffic roads.
2069	Limestone	0	45	96	98	98	2	Good	-------	Good	Concrete aggregate only.
2086	Limestone	15	58	95	98	98	2	-------	-------	-------	
2085	Limestone	30	73	91	94	94	6	Excell.	Excell.	Excell	

COOKE COUNTY

*5939	Limestone	0	13	82	91	95	5	Good	Excell.	Fair	Light traffic roads.

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

Laboratory No.	Characteristic Material Composing Gravel	Mechanical Analysis						Cementing Value			Recommendations
		Percent Retained on					Percent passing	Material			
		2-inch sieve	1-inch sieve	⅛-inch sieve	No. 48 sieve	No. 200 sieve	No. 200 sieve	Above ⅛-inch	Below ⅛-inch	As received	
	DALLAS COUNTY										
2470	Limestone	0	7	63	89	94	6	Good	Excell.	Excell.	Satisfactory.
*5936	Limestone and sandstone	0	7	72	94	98	2	Good	Excell.	Excell.	Very light traffic.
2168	Limestone	3	18	67	96	100	0	Fair	Good	Good	Concrete aggregate or R. R. ballast.
2453	Limestone	0	9	75	95	100	0				Concrete aggregate or R. R. ballast.
	DENTON COUNTY										
2467	Limestone	0	18	60	87	98	2	Good	Excell.	Good	Satisfactory.
2454	Limestone	0	21	77	96	99	1	Fair	Excell.	Good	Medium traffic.
2456	Chert and clay	0	0	45	69	74	26	Excell.	Excell.	Excell.	Binder course.
2466	Limestone and sandstone	2	17	61	76	84	16	Excell.	Excell.	Excell.	Very light traffic.
2458	Limestone	4	46	99				Excell.	Excell.	Excell.	
2468	Limestone	0	6	58	96	100	0				
	DeWITT COUNTY										
*8805	Chert and quartzite	23	48	85	96	99	1	Poor	Excell.	Good	
*8806	Chert and quartzite	24	50	83	98	100	0	Poor	Excell.	Fair	
	DUVAL COUNTY										
*6329	Quartz	0	23	86			5	Fair	Excell.	Good	Satisfactory.
	FAYETTE COUNTY										
1983	Quartz and flint	7	19	84	97	98	2	Poor	Good	Poor	
	GRAYSON COUNTY										
*5937	Limestone	0	2	73	91	95	5	Excell.	Excell.	Good	Very light traffic.
*5975	Limestone	0	5	62	88	93	7	Good	Good	Good	Very light traffic.
	GUADALUPE COUNTY										
2138	Limestone	9	28	77	93	95	5	Good	Excell.	Good	Satisfactory.
2140	Limestone	39	57	100							

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

HARRISON COUNTY

2548	Disintegrated sandstone	0	8	43	52	85	15	Fair	Fair	Fair	

HAYS COUNTY

2482	Limestone	16	37	73	84	87	13	Good	Excell.	Excell.	Very good.
2640	Hard chert	10	49	81	81	83	17	Poor	Excell.	Excell.	Heavy traffic road.
1930	Limestone	2	11	67	89	93	7	Fair	Excell.	Excell.	Good material.
1931	Limestone	10	34	78	92	93	7	Fair	Excell.	Excell.	Satisfactory.
2051	Limestone	5	22	89	93	96	4	Good	Good	Excell.	Heavy traffic.
2054	Limestone and clay	0	24	78	83	84	16	Fair	Excell.	Excell.	Satisfactory.
2053	Limestone and clay	0	8	65	85	88	12	Fair	Excell.	Good	Satisfactory.
2012	Limestone	6	13	78	94	95	5	Good	Excell.	Good	Satisfactory.
*7905	Limestone	0	25	73	96	97	3	Good	Good	Good	Satisfactory.
2065	Limestone and clay	0	27	77	87	88	12	Fair	Excell.	Excell.	Satisfactory if large stones removed.
2057	Limestone	0	39	84	91	93	7	Good	Excell.	Fair	Satisfactory.
2018	Limestone	0	9	77	91	93	7	Good	Good	Good	Satisfactory.
1985	Limestone	9	20	80	90	95	5	Fair	Excell.	Good	Satisfactory.
2023	Limestone	0	17	84	93	95	5	Fair	Good	Fair	Satisfactory.
2021	Limestone	0	11	85	90	94	6	Good	Excell.	Good	Satisfactory.
2011	Limestone and sandstone	4	7	54	85	87	13	Good	Excell.	Good	Satisfactory.
2017	Limestone conglomerate									Good	Satisfactory.
2020	Limestone and flint	21	54	87	90	91	9	Good	Excell.	Excell.	Satisfactory if large stones removed.
2032	Limestone	0	11	70	87	89	11	Good	Excell.	Good	Light traffic roads.
2027	Limestone	0	11	54	70	76	24	Good	Excell.	Good	Binder course.
2019	Limestone conglomerate									Good	
2026	Limestone conglomerate									Good	
2022	Limestone	4	37	55	68	81	19	Good	Excell.	Excell.	
2024	Limestone	6	49	99	100					Good	
2049	Limestone	4	48	100							
2067	Limestone	5	14	60	76	79	21	Good	Excell.	Excell.	
2025	Limestone	5	15	99	100					Good	
2050	Limestone	0	0	99	100					Good	
2052	Very soft limestone									Good	
2034	Shell adobe									Excell.	

ROBERTSON COUNTY

*7146	Limestone and quartz	0	6	47	81	94	6	Good	Excell.	Excell.	Too much sand.
*6914	Chert, sandstone	2	12	58	96	97	3	Good	Good	Good	Too much sand.
*7147	Limestone and quartz	0	11	57	94	97	3	Excell.	Excell.	Excell.	Too much sand.
*6915	Chert and sandstone	0	4	57	93	96	4	Poor	Fair	Fair	Too much sand.

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

Laboratory No.	Characteristic Material Composing Gravel	Mechanical Analysis						Cementing Value			Recommendations
		Percent Retained on					Percent passing	Material			
		2-inch sieve	1-inch sieve	⅛-inch sieve	No. 48 sieve	No. 200 sieve	No. 200 sieve	Above ⅛-inch	Below ⅛-inch	As received	
	RUSK COUNTY										
2654	Sandstone and clay	0	4	11	14	50	50	------	Excell.	Excell.	Satisfactory sand-clay road. See Plate XVIII.
2649	Iron sandstone	4	16	93	97	98	2	Excell.	Excell.	Excell.	Needs sand and clay.
2648	Quartz and clay	0	0	4	9	34	65	------	--------	Excell.	Needs about 80% of 2649.
2651	Sandstone and clay	0	0	0	7	38	62	------	--------	Excell.	
2652	Sandstone and clay	0	0	0	56	85	15	------	--------	Excell.	
	SAN PATRICIO COUNTY										
2037	Limestone and flint	0	3	44	67	78	22	------	--------	----------	
2038	Adobe and limestone	0	5	20	31	43	57	------	--------	----------	
	TARRANT COUNTY										
*4133	Shell and limestone	--------	--------	--------	--------	--------	--------	------	--------	Good	Light traffic roads.
*4134	Shell and limestone	--------	--------	--------	--------	--------	--------	------	--------	Good	Light traffic roads.
2330	Limestone and flint	0	21	61	97	100	--------	------	--------	----------	Good concrete aggregate.
	TRAVIS COUNTY										
1898	Limestone and chert	11	27	71	86	88	12	Good	Excell.	Excell.	Good material.
1894	Limestone	0	10	68	90	93	7	Fair	Good	Good	Satisfactory.
2177	Limestone and flint	5	21	66	87	94	6	Good	Excell.	Excell.	Satisfactory.
1890	Limestone	0	11	73	92	96	4	Good	Excell.	Good	Satisfactory.
1876	Limestone	3	12	70	94	97	3	Fair	Good	Good	Satisfactory.
1859	Limestone	8	20	76	97	98	2	Fair	Excell.	Fair	Satisfactory.
1873	Limestone	0	22	78	93	96	4	Fair	Good	Good	Satisfactory.
1893	Limestone	0	13	79	98	99	1	Fair	Good	Fair	Satisfactory.
1856	Limestone	0	6	67	89	94	6	Good	Excell.	Good	Satisfactory.
2352	Limestone	7	11	64	91	96	4	Good	Good	Good	Fair road material.
1886	Limestone	12	28	63	81	86	14	Good	Excell.	Good	Satisfactory.
2353	Limestone	14	26	83	95	96	4	Good	Good	Good	Satisfactory.
1855	Quartz and limestone	5	18	61	95	97	3	Good	Good	Excell.	Satisfactory.
1882	Limestone	5	12	64	83	88	12	Good	Good	Good	Satisfactory.

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

1853	Limestone	6	18	64	80	83	17	Good	Excell.	Excell.	Satisfactory.
1892	Limestone	6	14	64	92	96	4	Fair	Excell.	Good	Satisfactory.
1891	Limestone	8	16	63	93	96	4	Fair	Good	Fair	Satisfactory.
1895	Limestone	4	11	64	89	95	5	Good	Good	Good	Satisfactory.
1857	Limestone and flint	0	9	50	87	93	7	Excell.	Excell.	Excell.	Satisfactory.
2355	Hard limestone	5	18	84	99	100	0	------	------	------	Good concrete aggregate.
1872	Flint and quartz	0	2	40	85	89	11	Fair	Excell.	Excell.	Binder course.
1869	Limestone	0	1	49	83	91	9	Fair	Good	Good	Binder course.
1881	Flint and quartzite	0	3	36	82	86	14	Fair	Excell.	Excell.	Binder course.
1878	Limestone	0	18	72	86	90	10	Good	Excell.	Excell.	Light traffic material.
1862	Limestone	5	21	64	84	87	13	Good	Excell.	Fair	Light traffic material.
1858	Flint and quartzite	17	38	57	84	88	12	Good	Excell.	Excell.	Satisfactory if large stones removed.
1932	Limestone	5	16	69	81	85	15	Good	Excell.	Excell.	Light traffic material.
1884	Limestone	0	9	66	80	84	16	Good	Excell.	Good	Light traffic material.
1879	Limestone and shell	0	9	65	76	79	21	Excell.	Excell.	Excell.	
2130	Flint and quartzite	0	6	51	89	94	6	Fair	Good	Fair	
2321	Flint and quartzite	3	9	49	81	86	14	Poor	Excell.	Good	
1877	Limestone	0	6	58	80	86	14	Good	Excell.	Good	
188[illegible]	Limestone	0	11	51	68	72	28	Good	Excell.	Excell.	
1863	Flint and quartzite	0	2	17	78	88	12	Fair	Excell.	Excell.	
1846	Quartz and feldspar	0	0	42	89	92	8	Good	Excell.	Excell.	Too much sand.
1854	Limestone	42	80	100	------	------	0	------	------	Good	
1864	Quartz and feldspar	0	6	48	88	90	10	Poor	Excell.	Excell.	
1866	Flint and limestone	8	11	48	67	73	27	Excell.	Excell.	Excell.	
1870	Flint and limestone	23	26	53	95	98	2	Good	Good	Good	
1865	Flint and limestone	0	5	34	82	86	14	Good	Excell.	Excell.	
1897	Flint and quartz	5	12	41	79	82	18	Excell.	Excell.	Excell.	Too much sand.
2313	Flint and quartz	0	6	35	76	83	17	Poor	Excell.	Excell.	
2319	Flint and quartz	0	5	30	73	78	22	Fair	Excell.	Excell.	
2320	Quartz and feldspar	0	1	27	73	77	23	Good	Excell.	Excell.	
2323	Quartz and flint	0	1	36	83	88	12	Good	Excell.	Excell.	
2314	Quartz and feldspar	0	1	34	75	81	19	Poor	Excell.	Excell.	
2175	Quartz and feldspar	0	0	47	77	79	21	Poor	Excell.	Excell.	
2176	Quartz and feldspar	0	4	43	76	79	21	Fair	Excell.	Excell.	
1885	Limestone and flint	0	13	47	60	65	35	Good	Excell.	Excell.	
1883	Limestone	0	16	63	72	77	23	Good	Excell.	Excell.	
1867	Quartz and flint	0	1	30	67	79	21	Fair	Excell.	Excell.	
1868	Quartz and feldspar	0	0	41	83	87	13	Fair	Excell.	Excell.	
1871	Quartz and flint	0	3	31	73	84	16	Fair	Excell.	Excell.	
1880	Quartz and flint	0	5	24	63	67	33	Fair	Excell.	Excell.	
2207	Quartz and flint	0	6	28	68	84	16	Fair	Excell.	Excell.	
1974	Shell adobe	------	------	------	------	------	------	------	------	Good	

VICTORIA COUNTY

2262	Flint and quartz	0	10	79	95	99	1	Poor	Good	Good	Surface treated road.

TESTS ON GRAVELS, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL—Continued

Laboratory No.	Characteristic Material Composing Gravel	Mechanical Analysis: Percent Retained on 2-inch sieve	1-inch sieve	⅛-inch sieve	No. 48 sieve	No. 200 sieve	Percent passing No. 200 sieve	Cementing Value: Material Above ⅛-inch	Below ⅛-inch	As received	Recommendations
	WILLIAMSON COUNTY										
1945	Limestone	0	18	78	89	91	9	Good	Excell.	Excell.	Satisfactory.
1947	Limestone	0	12	53	65	66	34	Excell.	Excell.	Excell.	Binder course.
1956	Limestone	11	33	85	96	96	4	Good	Excell.	Good	
	WOOD COUNTY										
2567	Iron sandstone	7	21	71	86	91	9	Fair	Excell.	Good	Very good material.
2568	Iron sandstone	3	17	68	83	92	8	Good	Excell.	Good	Satisfactory.
2559	Iron sandstone	0	1	57	72	99	1	------	------	------	
2557	Iron sandstone	20	28	56	62	74	26	Good	Good	Good	
2535	Iron sandstone	10	19	55	65	77	23	Good	Excell.	Good	
2558	Iron sandstone	8	14	39	46	57	43	Fair	Good	Good	
2536	Iron sandstone	0	2	17	26	42	58	Good	Excell.	Good	
2537	Iron sandstone	6	19	46	54	67	33	Good	Excell.	Excell.	Binder course.
2538	Iron sandstone	0	1	31	48	77	23	Good	Good	Good	
2539	Iron sandstone	0	0	9	16	34	66	Excell.	Excell.	Excell.	

TESTS ON LIMESTONE, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French coefficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs. per sq. in.	Kind of Traffic for Which Material Is Recommended: Waterbound Macadam	Kind of Traffic for Which Material Is Recommended: Bituminous Construction
				BEXAR COUNTY					
*1199	153	4.89	------	------	4	42	------	Tests incomplete	Tests incomplete
*1200	131	13.2	------	------	------	62	------	Tests incomplete	Tests incomplete
*1201	143	8.68	------	------	------	46	------	Tests incomplete	Tests incomplete
*1202	143	8.29	------	0.0	3	21	------		
*1229	159	2.19	7.8	7.1	4	42	------	Very light traffic	Very light traffic
				BURNET COUNTY					
1821	165	0.67	16.1	18.2	14	42	24,500	Heavy traffic	Heavy traffic
1820	165	1.67	14.8	15.7	16	118	19,950	Heavy traffic	Heavy traffic
1808	165	0.72	14.6	16.3	9	28	17,700	Heavy traffic	Heavy traffic
1794	168	0.31	13.5	16.0	6	72	18,860	Medium traffic	Heavy traffic
1795	168	0.44	13.3	16.8	7	50	15,425	Medium traffic	Heavy traffic
1822	168	0.30	12.3	16.4	6	81	18,575	Medium traffic	Heavy traffic
1816	168	0.25	13.2	17.8	6	25	15,025	Medium traffic	Heavy traffic
1827	168	1.11	14.4	14.7	5	87	16,250	Light traffic	Medium traffic
1830	168	0.33	12.3	15.2	5	49	13,085	Light traffic	Medium traffic
1832	168	0.53	13.0	14.5	7	12	16,250	Light traffic	Medium traffic
1811	168	0.22	12.1	13.4	4	76	12,575	Light traffic	Medium traffic
1793	168	0.76	9.7	15.2	5	78	10,040	Light traffic	Medium traffic
1791	172	0.42	11.1	14.5	7	21	17,000	Light traffic	Medium traffic
1809	168	0.69	11.3	15.2	5	23	16,100	Light traffic	Medium traffic
1817	168	0.19	12.1	14.8	4	33	13,160	Light traffic	Medium traffic
1807	162	1.70	11.5	13.7	6	34	11,075	Light traffic	Medium traffic
1803	168	0.55	8.7	15.2	7	74	9,975	Light traffic	Medium traffic
1806	153	3.62	11.0	13.2	6	24	11,160	Light traffic	Medium traffic
1796	168	0.81	8.8	15.3	3	70	11,860	------------------	Medium traffic
1802	168	1.94	8.3	16.5	4	49	10,875	Light traffic	Light traffic
1813	168	0.17	10.0	14.7	4	17	16,850	------------------	Medium traffic
1825	168	0.17	11.3	11.5	5	54	12,100	Light traffic	Medium traffic
1792	175	1.16	8.9	13.7	6	34	13,140	Light traffic	Medium traffic
1823	168	0.26	9.0	15.1	4	21	11,965	Light traffic	Medium traffic
1826	168	1.58	9.3	10.8	4	19	12,475	Light traffic	Medium traffic
1801	168	0.52	8.0	12.0	4	28	11,000	Light traffic	Medium traffic
1833	168	0.32	11.7	14.8	3	42	14,350	Light traffic	Medium traffic
				COMAL COUNTY					
2099	162	1.58	9.5	12.6	5	10	------	Light traffic	Medium traffic
*7609	165	0.12	8.3	13.2	6	20	------	Light traffic	Light traffic
1979	165	0.72	10.6	13.7	4	13	14,500	Light traffic	Light traffic
1980	162	0.89	6.6	9.8	4	18	7,725		
1978	156	2.75	7.8	8.5	5	11	7,350		
2286	156	2.87	5.9	8.2	3	15	6,000		
2324	153	2.69	5.1	5.5	6	19	9,220		
2326	156	1.35	2.4	4.9	3	31	4,230		
2327	139	5.23	2.9	0.0	4	19	4,170		
2325	165	0.42	1.9	0.0	2	39	3,170		
				DALLAS COUNTY					
2310	124	14.1	4.0	0.0	2	233	3,200		
2311	118	17.5	1.7	0.0	1	35	1,575		
				DEAF SMITH COUNTY					
2483	159	3.30	2.2	0.0	5	500+	9,650		
				DENTON COUNTY					
2452	162	2.28	7.9	14.2	5	23	15,000	Medium traffic	Medium traffic
2469	159	2.86	9.5	13.4	4	48	13,850	Light traffic	Medium traffic

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

TESTS ON LIMESTONE, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL—Continued

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French co-efficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs. per sq. in.	Kind of Traffic for Which Material Is Recommended: Waterbound Macadam	Bituminous Construction
EASTLAND COUNTY									
2231	159	2.62	9.6	10.5	5	51	11,350	Light traffic	Medium traffic
2217	162	2.42	------	12.9	5	28	12,250	Light traffic	Light traffic
2211	162	1.99	------	11.8	4	66	12,325	Light traffic	Light traffic
ERATH COUNTY									
*7297	168	0.64	6.0	14.6	4	50	------	Light traffic	Light traffic
FAYETTE COUNTY									
2091	140	3.81	3.5	17.7	9	43	15,325		
2116	165	1.56	5.8	9.7	2	66	-----		
2090	156	4.08	------	0.0	3	198	5,617		
GRAYSON COUNTY									
*1480	162	1.94	9.2	15.4	9	81	------	Medium traffic	Medium traffic
*3414	162	2.20	------	15.9	11	23	------	Medium traffic	Medium traffic
*3413	159	2.71	------	15.6	8	74	------	Medium traffic	Medium traffic
*1479	159	2.77	7.7	12.8	8	107	------	Light traffic	Light traffic
*5852	159	2.87	6.0	14.6	6	50	------	Light traffic	Light traffic
*5642	162	2.12	7.0	13.7	8	50	------	Light traffic	Light traffic
*5851	159	3.65	5.6	14.8	5	50	------	Light traffic	Light traffic
*3142	153	5.65	------	12.3	5	101	------		
*5938	134	12.0	5.3	0.0	3	75	------		
HAYS COUNTY									
2070	165	1.06	11.1	16.5	5	29	16,050	Medium traffic	Medium traffic
2055	162	2.15	10.7	14.2	7	42	11,000	Light traffic	Medium traffic
2014	156	3.34	9.9	13.9	6	12	13,375	------------------	Medium traffic
1929	156	4.50	11.6	10.6	5	9	10,025	Light traffic	Light traffic
2013	165	1.10	8.9	13.3	4	15	10,650	------------------	Light traffic
2033	162	1.92	7.0	14.4	5	8	------	------------------	Light traffic
2056	159	3.44	8.3	9.3	5	38	10,750	------------------	Very light traffic
2031	162	1.47	7.0	9.9	4	14	7,790	------------------	Very light traffic
2030	159	2.35	6.8	10.0	4	16	8,650	------------------	Very light traffic
2015	159	2.36	7.6	8.7	4	15	10,260	------------------	Very light traffic
2029	150	5.99	5.3	0.0	3	99	8,050		
2028	147	7.56	6.2	0.0	3	52	------		
HIDALGO COUNTY									
2105	162	2.26	8.0	12.3	5	184	13,000	Light traffic	Medium traffic
HILL COUNTY									
*2685	143	8.60	4.2	------	------	39	------	Test incomplete	Test incomplete
JACK COUNTY									
*5395	168	0.82	8.2	14.8	9	50	------	Medium traffic	Medium traffic
*7332	165	1.27	10.6	14.1	6	100+	------	Medium traffic	Medium traffic
*7331	165	1.63	7.7	13.5	4	75	------	Very light traffic	Very light traffic
*3869	165	1.94	8.0	------	------	52	------	Very light traffic	Very light traffic
KAUFMAN COUNTY									
*7015	162	1.63	4.4	14.5	7	100+	------	Light traffic	Light traffic
*7016	156	2.92	3.4	5.0	4	100+	------		
*6314	153	4.11	3.3	------	------	100+	------		
LIMESTONE COUNTY									
*8501	162	1.45	8.9	15.0	7	50	------	Light traffic	Light traffic
*7224	159	2.28	5.2	7.8	4	100+	------	Very light traffic	Very light traffic

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

TESTS ON LIMESTONE, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL—Continued

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French coefficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs. per sq. in.	Kind of Traffic for Which Material Is Recommended: Waterbound Macadam	Kind of Traffic for Which Material Is Recommended: Bituminous Construction
				MONTGOMERY COUNTY					
*7190	165	1.38	9.3	12.4	10	75	------	Light traffic	Medium traffic
				McLENNAN COUNTY					
2520	140	1.46	4.6	0.0	2	176	3,175		
				NAVARRO COUNTY					
*7209	168	1.02	10.5	13.3	4	100+	------	Light traffic	Medium traffic
*7070	168	0.60	7.3	14.1	6	15	------	Light traffic	Medium traffic
*5955	165	1.33	6.5	15.6	9	50	------	Light traffic	Medium traffic
				NOLAN COUNTY					
*4327	159	2.76	6.4	13.7	5	21	------	Light traffic	Light traffic
*4532	159	1.67	6.5	13.3	4	15	------	Light traffic	Light traffic
				PALO PINTO COUNTY					
2484	165	0.54	9.2	12.5	7	93	8,125	Light traffic	Medium traffic
*6579	168	0.37	9.5	13.5	6	50	------	Light traffic	Medium traffic
*4131	165	1.22	7.3	14.5	7	60	------	Light traffic	Medium traffic
				RED RIVER COUNTY					
2518	131	2.11	3.3	0.0	3	137	1,920		
				TAYLOR COUNTY					
*5155	165	1.50	9.9	14.2	7	15	------	Medium traffic	Medium traffic
				TRAVIS COUNTY					
1787	159	2.90	11.4	14.9	9	39	16,275	Medium traffic	Medium traffic
1937	168	0.81	13.7	14.9	5	26	13,300	Medium traffic	Medium traffic
1958	165	1.29	11.7	14.5	6	39	14,050	Medium traffic	Medium traffic
1941	162	2.06	12.6	13.8	5	26	10,720	Medium traffic	Medium traffic
1940	165	1.34	11.9	12.8	7	39	13,050	Medium traffic	Medium traffic
1887	162	2.78	10.9	15.2	7	15	15,000	Medium traffic	Medium traffic
1967	165	0.77	10.2	15.3	5	39	18,225	Medium traffic	Medium traffic
1971	162	1.41	10.2	15.1	5	39	15,620	Medium traffic	Medium traffic
1837	165	0.89	10.9	15.4	4	16	15,725	Medium traffic	Medium traffic
1975	165	1.43	9.4	14.5	5	50	15,350	Light traffic	Medium traffic
1781	165	1.23	10.8	14.4	5	23	13,875	Light traffic	Medium traffic
1966	153	3.51	10.9	10.2	4	20	10,150	Light traffic	Light traffic
1964	165	0.87	9.5	15.6	7	16	9,975	Light traffic	Medium traffic
1933	165	1.56	11.0	13.8	6	18	13,750	Light traffic	Medium traffic
1785	150	3.24	10.0	14.5	6	14	12,710	Light traffic	Medium traffic
1786	165	1.49	11.1	13.8	4	15	14,600	Light traffic	Medium traffic
1838	162	1.55	9.6	14.5	6	13	16,350	Light traffic	Medium traffic
1936	162	1.94	11.2	11.9	5	20	11,340	Light traffic	Medium traffic
1875	162	1.35	9.8	14.3	6	8	15,425	------	Medium traffic
1900	165	1.33	8.8	14.8	4	13	11,400	Light traffic	Light traffic
1899	162	2.16	10.9	11.6	5	7	10,380	------	Light traffic
1960	156	1.62	8.3	11.8	4	76	11,060	Light traffic	Light traffic
1977	159	3.09	9.7	12.0	5	16	14,775	Light traffic	Medium traffic
1841	168	0.39	8.7	13.3	4	20	10,812	Light traffic	Light traffic
2457	162	4.06	8.7	12.2	7	41	13,200	Light traffic	Light traffic
1836	159	3.56	9.2	11.9	4	39	10,150	Light traffic	Light traffic
1959	156	4.09	8.8	10.4	5	62	12,125	Light traffic	Light traffic
1961	156	2.04	8.7	11.5	6	21	11,750	Light traffic	Light traffic
1973	165	2.00	9.3	11.5	4	18	11,940	Light traffic	Light traffic
1962	162	1.00	8.8	11.6	4	22	4,520	Light traffic	Light traffic
1935	159	3.36	9.5	10.5	4	15	7,500	Light traffic	Light traffic

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

TESTS ON LIMESTONE, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL—Continued

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French coefficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs. per sq. in.	Kind of Traffic for Which Material Is Recommended: Waterbound Macadam	Bituminous Construction
				TRAVIS COUNTY—Continued					
1834	153	2.22	9.0	11.4	3	16	8,725	------	Light traffic
1835	159	2.31	8.1	12.0	4	13	10,400	------	Light traffic
1843	159	1.99	7.5	18.3	4	17	11,125	Very light traffic	Very light traffic
1970	159	2.19	9.6	15.0	3	15	13,525		
1788	162	0.69	9.8	16.5	3	20	17,750		
1963	162	1.09	8.2	17.4	3	51	10,100		
1943	162	1.62	11.0	12.8	5	11	10,000	Light traffic	Medium traffic
1874	165	0.44	10.5	13.8	5	5	13,300	------	Medium traffic
1902	162	1.62	10.5	13.3	2	21	11,040		
1965	162	0.87	8.3	11.8	4	53	10,225	Light traffic	Light traffic
1839	162	1.95	7.6	14.6	4	17	10,810		
1969	162	1.85	8.4	11.3	4	49	14,450		
1840	156	3.44	7.0	11.2	5	35	10,840	Very light traffic	Very light traffic
1976	159	2.55	7.9	10.5	4	26	8,400		
1841	162	2.76	7.5	11.9	3	11	15,365		
1931	156	3.30	7.7	6.9	4	18	10,035		
1842	156	4.21	6.9	5.7	4	15	7,073		
1968	150	1.59	7.1	3.9	3	24	8,450		
1860	153	4.43	5.2	6.5	3	22	6,115		
2259	143	4.95	2.7	0.0	3	23	4,825		
1861	150	1.48	1.1	0.0	3	22	1,975		
1942	159	3.49	------	------	------	44	------		
				WILLIAMSON COUNTY					
1951	------	------	13.5	13.8	7	15	17,050	Medium traffic	Medium traffic
1946	162	2.14	11.7	13.8	6	38	13,400	Medium traffic	Medium traffic
1944	162	1.66	13.2	14.3	7	11	13,725	Medium traffic	Medium traffic
1950	162	2.95	13.0	13.3	7	29	15,050	Medium traffic	Medium traffic
1954	162	2.64	9.1	15.2	5	29	11,550	Light traffic	Medium traffic
1955	162	2.70	9.3	15.2	5	19	13,400	Light traffic	Medium traffic
1952	156	1.78	9.2	9.5	4	14	11,250	Light traffic	Medium traffic
1948	156	3.72	9.5	11.1	4	44	8,950	Light traffic	Medium traffic
*2707	159	2.64	5.6	13.2	4	46	------	Light traffic	Light traffic
1984	153	5.04	7.2	7.8	4	30	9,050		
1953	150	6.78	7.3	7.5	2	47	6,190		
1957	150	5.03	5.3	3.7	3	9	8,140		
*2706	156	3.20	3.8	0.0	4	23	------		
*2708	153	5.06	1.7	5.3	3	10	------		
1949	142	6.16	1.3	0.0	2	17	4,025		
				WISE COUNTY					
2170	168	0.31	10.2	15.0	6	16	11,425	Medium traffic	Medium traffic
*7242	168	0.37	9.3	14.1	4	50	------	Light traffic	Medium traffic
*6683	168	0.26	------	15.6	6	50	------	Light traffic	Medium traffic
*4412	168	0.34	7.3	14.3	5	50	------	Light traffic	Medium traffic
*6684	168	0.36	6.6	14.6	6	50	------	Light traffic	Light traffic
*6667	168	0.60	6.2	13.8	5	50	------	Light traffic	Light traffic
*6600	165	1.03	5.9	12.2	6	50	------		

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

TESTS ON DOLOMITES, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French co-efficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs. per sq. in.	Kind of Traffic for Which Material Is Recommended: Waterbound Macadam	Kind of Traffic for Which Material Is Recommended: Bituminous Construction
								BURNET COUNTY	
1824	175	0.29	16.4	15.6	11	53	26,250	Medium traffic	Heavy traffic
1814	175	0.46	15.6	17.3	8	43	26,000	Medium traffic	Heavy traffic
1810	175	0.39	13.8	16.3	9	25	22,000	Medium traffic	Heavy traffic
1805	175	0.44	12.9	16.3	7	17	16,725	Medium traffic	Medium traffic
1818	175	0.35	11.3	16.1	8	41	25,000	Medium traffic	Medium traffic
1831	175	0.53	11.8	15.7	7	42	15,770	Medium traffic	Medium traffic
1829	175	0.22	10.2	15.8	7	40	19,100	Medium traffic	Medium traffic
1804	175	0.59	9.8	16.3	9	18	18,150	Medium traffic	Medium traffic
1812	175	0.34	10.9	15.5	4	18	16,440	------	Medium traffic
1828	172	0.40	7.5	15.2	6	80	16,830	Light traffic	Medium traffic
1815	175	1.03	10.0	14.1	4	19	18,650	------	Medium traffic
1819	168	1.90	8.5	12.8	5	20	19,000	Light traffic	Medium traffic

TESTS ON SANDSTONES, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French co-efficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs. per sq. in.	Waterbound Macadam	Bituminous Construction
								ANDERSON COUNTY	
2673	187	1.40	13.4	18.8	6	81	26,300	Medium traffic	Heavy traffic
								BURLESON COUNTY	
*1500	140	3.50	9.6	16.7	14	13	------	------	Medium traffic
								BURNET COUNTY	
1799	153	3.74	8.8	14.8	10	96	15,750	------	Medium traffic
								FAYETTE COUNTY	
1982	134	7.64	9.7	17.8	15	18	14,075	------	Medium traffic
								GRAYSON COUNTY	
2260	184	1.67	13.1	19.3	14	22	10,700	------	Medium traffic
								HARRISON COUNTY	
*1958	153	0.52	1.7	2.7	3	176	------		
								LAMAR COUNTY	
*3147	143	7.25	3.5	0.0	4	50	------		
								RUSK COUNTY	
2650	178	2.28	8.0	14.9	2	33	25,750	------	Medium traffic
								SMITH COUNTY	
*6398	165	0.77	9.3	15.3	6	104	------	Light traffic	Medium traffic
*6396	162	0.33	9.5	18.8	6	5	------	------	Medium traffic
								WASHINGTON COUNTY	
*1499	143	2.67	7.9	16.7	12	93	------	------	Medium traffic
								WOOD COUNTY	
2560	178	11.2	1.9	------	------	20	5,675		

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

TESTS ON SYENITES AND GRANITES, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French coefficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs per sq. in.	Kind of Traffic for Which Material Is Recommended: Waterbound Macadam	Kind of Traffic for Which Material Is Recommended: Bituminous Construction
					EL PASO COUNTY				
*2185	159	1.68	15.7	18.2	9	257	------	Medium traffic	Medium traffic
*3727	159	1.40	9.9	18.1	13	150	------	Medium traffic	Medium traffic
*2084	159	1.58	2.8	18.2	11	200	------		
					GRAYSON COUNTY				
*5709	162	1.61	8.3	19.3	8	75	------	------	Medium traffic

TEST ON GABBRO AND GRANITE FROM LLANO COUNTY, UP TO SEPTEMBER 1, 1915

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French coefficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs per sq. in.	Waterbound Macadam	Bituminous Construction
					LLANO COUNTY				
2574	165	------	------	18.8	15	9	20,300	Good granite paving block	
2675	172	0.21	23.0	18.5	18	26	26,500	Heavy traffic	Heavy traffic

TESTS ON BASALT, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French coefficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs per sq. in.	Waterbound Macadam	Bituminous Construction
					TRAVIS COUNTY				
2496	200	0.37	24.7	19.0	28	35	46,660	Very heavy traffic	Very heavy traffic
					UVALDE COUNTY				
*7120	193	0.39	22.2	17.5	15	50	34,000	Heavy traffic	Very heavy traffic

TESTS ON CHALKY LIMESTONE FROM TRAVIS COUNTY, UP TO SEPT. 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French coefficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs per sq. in.	Waterbound Macadam	Bituminous Construction
					TRAVIS COUNTY				
1893	------	------	------	------	------	------	------		
1972	------	------	------	------	------	79	------		
1771	------	------	------	------	------	62	----		

TESTS ON CONGLOMERATES, UP TO SEPTEMBER 1, 1915, ARRANGED IN COUNTIES ACCORDING TO VALUE AS ROAD MATERIAL

Laboratory No.	Weight lbs. per cubic ft. solid	Lbs. of water absorbed per cubic ft.	French coefficient of wear	Hardness coefficient	Toughness—height of blow	Cementing value	Compressive strength lbs per sq. in.	Waterbound Macadam	Bituminous Construction
					ANDERSON COUNTY				
2671	------	------	------	------	------	500+	------	Light traffic	Light traffic
					ATASCOSA COUNTY				
2008	175	2.14	1.4	18.5	2	47	7,600		
					HARRISON COUNTY				
2545	------	------	------	------	------	34	------		
2546	------	------	------	------	------	29	------		
2547	175	7.63	1.7	------	------	32	4,670		
					LAMAR COUNTY				
*5532	159	0.49	8.1	19.4	10	5	------	Light traffic	Medium traffic
					RUSK COUNTY				
2653	------	------	------	------	------	100+	------		
					WOOD COUNTY				
2561	168	5.54	1.1	------	------	45	2,175		
2562	165	5.04	1.8	------	------	29	------		
2566	------	------	------	------	------	39	------		

*Samples tested by U. S. Office of Public Roads, Washington, D. C.

LOCATIONS OF MATERIALS INCLUDED IN TABLES

Tested in the Laboratory of the Bureau of Economic Geology, up to September 1, 1915

Laboratory No.	Location
1784	Old Walsh quarry, near end of I. & G. N. track, Austin branch, Travis County.
1785	Old Taylor quarry at lime kiln, near end of I. & G. N. track, Austin dam, Travis County.
1786	Old Johnson quarry, Deep Eddy, Colorado river, near Austin, Travis County.
1787	From near Spicewood Springs, Travis County, 7 miles west of north of Austin, within half a mile of I. & G. N. railroad.
1788	Same as 1787.
1791	Lefthand fork of Wood's Branch above Wood's sandstone quarry, Burnet County.
1792	Righthand fork, Wood's Branch, above Wood's sandstone quarry, Burnet County.
1793	Ferguson place, near Fairlands, Burnet County. Within half a mile of the A. & N. W. railroad.
1794	Same as 1793.
1795	At Hoover's Point, about 1¼ miles east of Colorado river bridge and directly on the A. & N. W. railroad.
1796	Same as 1795.
1799	Same as 1795.
1801	A. H. Edwards's land, about 1 mile east of A. & N. W. railroad and about 1½ miles southeast of Fairlands, Burnet County. Bottom strata.
1802	Same as 1801. Center strata.
1803	Same as 1801. Top strata.
1804	Dave Holland's land, about 1 mile south of A. & N. W. railroad and about 1¾ miles southeast of Fairlands, Burnet County.
1805	Reed Yett's land, about ½ mile south of A. & N. W. railroad and about 1¾ miles southeast of Fairlands, Burnet County.
1806	Reed Yett's land, about ¼ mile north of A. & N. W. railroad and about 1½ miles east of Fairlands, Burnet County. Lower part of the hill.
1807	Same as 1806. Center of hill.
1808	Same as 1806. Top of hill.
1809	Reed Yett's land, about ½ mile north of A. & N. W. railroad and about 1¾ miles east of Fairlands, Burnet County.

Laboratory No.	Location
1810	Reed Yett's land, about 200 yds. south of A. & N W. railroad and about 1¾ miles east of Fairlands, Burnet County. East of ranch house.
1811	Reed Yett's land, about ¼ mile west of A. & N. W. railroad and about 5 miles northeast of Fairlands, Burnet County, on Honey creek, above the bridge.
1812	Same as 1811. Below the bridge.
1813	Reed Yett's land, about ½ mile east of A. & N. W. railroad and about 5 miles east of Fairlands, Burnet County, on Honey creek, below the bridge.
1814	Same as 1813.
1815	E. O. Wengren's land, about ½ mile east of A. & N. W. railroad and about 6 miles east of Fairlands, Burnet County. About ¼ mile up Hamilton creek from its junction with Delaware creek.
1816	R. H. Hoover's land, about ½ mile east of A. & N. W. railroad and about 6 miles east of Fairlands, Burnet County, about 150 yds. above pumping station on Hamilton creek.
1817	R. H. Hoover's land, about ½ mile east of A. & N. W. railroad and about 6 miles east of Fairlands, Burnet County, about ¼ mile down Hamilton creek from pumping station.
1818	See 1817. About ¾ mile down Hamilton creek from pumping station, east side of creek.
1819	R. H. Hoover's land, immediately on track of A. & N. W. railroad west side of Delaware creek, and about 6 miles east of Fairlands, Burnet County.
1820	About 1 mile northeast of A. & N. W. station at Marble Falls, Burnet County, and ½ mile east of high school building.
1821	Backbone creek (Lacey's pasture), about ½ mile east of A. & N. W. railroad where creek cuts through ridge, about 1¼ miles north of railroad station at Marble Falls.
1822	Cut through Backbone Ridge, A. & N. W. railroad, about 1 mile north of Marble Falls, Burnet County.
1823	Widow Holland's ranch, about 1½ miles southeast of Burnet, Burnet County, and about ¾ mile east of A. & N. W. railroad, east side of Amazon creek.
1824	Bryant ranch, about ¾ mile down Hamilton creek, below Holland Spring, at point where the Holland branch empties into Hamilton creek, about ¾ mile east of A. & N. W. railroad, and about 3 miles south of Burnet, Burnet County.

Laboratory No.	Location
1825	R. H. Hoover's land. Burnet-Marble Falls road, hill just north of Hoover's ranch house, Burnet County, about 1 mile west of A. & N. W. railroad, and about 3½ miles southwest of Burnet.
1826	From cut on A. & N. W. railroad, 1 mile south of Delaware water tank, Burnet County.
1827	R. H. Hoover's land, about 400 yds. west of location of No. 1826, about 1 mile south of Delaware water tank, A. & N. W. railroad, Burnet County.
1828	Reed Yett place, about ½ mile up Honey creek, from A. & N. W. railroad bridge, Burnet County, about ¼ mile west of track, about 5 miles east of Fairlands.
1829	Reed Yett's land, about ¾ mile up Honey creek, Burnet County, from the crossing of the A. & N. W. railroad and about ¼ mile west of the track, about 5 miles east of Fairlands.
1830	R. H. Hoover's land, about 1 mile up Honey creek from crossing of A. & N. W. railroad, and about ¾ mile from the railroad, Burnet County.
1831	Reed Yett's land, first creek north from Sudduth section-house, on A. & N. W. railroad, Burnet County, about ½ mile down the cretk.
1832	About ¾ mile north of Sudduth sectionhouse on A. & N. W. railroad, Burnet County, west side of the railroad and up the creek about 450 yds.
1833	A short distance south of Honey creek, west side of A. & N. W. railroad, Burnet County.
1834	Barton Creek, Travis County, about ¾ mile above Barton Springs.
1835	Barton Creek, Travis County, about 1 mile above Barton Springs.
1836	South side of county road near Camp Mabry, Travis County, about 1 mile west of I. & G. N. railroad.
1837	J. A. Patton's land, about 8 miles southwest of Austin, Travis County, west of Fredericksburg road, near Oak Hill, about 5 miles west of I. & G. N. railroad.
1838	About 1 mile from Oak Hill, near Fredericksburg road, Travis County, about 4 miles west of I. & G. N. railroad.
1839	About 5 miles west of south of Austin, Travis County, and about ¾ mile west of I. & G. N. railroad, Dripping Springs road.
1840	Fredericksburg road within city limits of Austin, Travis County, about 200 yds. west of I. & G. N. railroad.
1841	Bear Creek, Travis County, a short distance above junction with Onion Creek, about ½ mile east of the I. & G. N. railroad and about 1 mile southeast of Manchaca.

Laboratory No.	Location
1842	Bear Creek, Travis County, a short distance above junction with Onion Creek, about half mile east of I. & G. N. railroad and about 1 mile southeast of Manchaca, higher up creek than sample No. 1841.
1843	Slaughter Creek, Travis County, a mile north of Manchaca, and about ¼ mile west of I. & G. N. railroad.
1844	On Austin and Manchaca road, about ¼ mile west of I. & G. N. railroad, and about 400 yds. north of sample represented by Anal. 1843.
1846A	Near Insane Asylum, Austin, Travis County.
1846B	Same as 1846A.
1853	Near St. Edwards College, Austin, Travis County, about 3 miles south of Austin, on San Antonio-Austin road.
1854	Bed of Barton Creek, about 500 yds. above Barton Springs, near Austin, Travis County.
1855	Bed of Colorado river at south end of bridge at Austin, Travis County.
1856	Sheppard pit, about 1 mile south of Del Valle store, near Creedmoor road, Travis County. See Plate XVI.
1857	About 1 mile west of Montopolis bridge, across Colorado river, near Austin, Travis County.
1858	County pit, about 1 mile south of Montopolis bridge, across Colorado river, Travis County.
1859	County pit, at Onion creek bridge, Creedmoor road, Travis County.
1860	Up Onion creek from bridge on Creedmoor road, about 500 yds., Travis County.
1861	E. Martin's quarry, on Onion creek, Travis County, about a mile above the bridge on Creedmoor road.
1862	From Cullen pit, on old Creedmoor road, about 6 miles southeast of Austin, Travis County.
1863	Roger's hill, Webberville road, about 7 miles south of east of Austin, Travis County.
1864	Near Ft. Prairie, Webberville road, about 5 miles south of east of Austin, Travis County.
1865	Pit on Webberville road, about 2 miles from Austin, Travis County.
1866	City pit on Washington Ave., Austin, Travis County.
1867	Pit on Manor road, 2 miles east of Austin, Travis County.
1868	County pit, 4 miles east of Austin, Travis County, on Manor road.
1869	Hamilton pit, 5 miles east of Austin, Travis County, on Manor road.
1870	McEachern pit, 12 miles southeast of Austin, Travis County, on Webberville road.

Laboratory No.	Location
1871	Littlepage's pit, 11 miles southeast of Austin, Travis County, on Webberville road.
1872	Joe Hornsby pit, on Webberville road, 9 miles southeast of Austin, Travis County.
1873	Pit on land of Chas. Davidson, Austin-Bastrop road, east of Onion creek and about 9 miles from Austin, Travis County.
1874	Old Zilker quarry, opposite Barton Springs, near Austin, Travis County.
1875	Same as 1874.
1876	Zilker pit, near Barton Springs, near Austin, Travis County.
1877	August Anson pit, on Cameron road at Buttermilk creek, 6 miles northeast of Austin, Travis County.
1878	Bill Dunstan pit, on Cameron road at Little Walnut creek, about 7 miles northeast of Austin, Travis County.
1879	J. Maxwell pit, on Cameron road, just across Big Walnut creek, about 9 miles northeast of Austin, Travis County.
1880	Morgan Huling pit, Chican Street, near Rosewood Ave., Austin, Travis County.
1881	Hamilton pit, 2½ miles northeast of Austin, Travis County.
1882	Miller pit, 3 miles south of Austin, Travis County.
1883	E. C. Ratliffe pit, 3½ miles south of Austin, Travis County.
1884	W. K. Beckitt pit, 6 miles south of Austin, Travis County.
1885	Bartholomew pit, 4 miles southwest of Austin, Travis County.
1886	Geo. Smith pit, Austin-Fredericksburg road, 5 miles southwest of Austin, Travis County.
1887	Bartholomew pit, old Michel place, about 3½ miles southwest of Austin, Travis County, near Fredericksburg road.
1889	T. W. Medearis, 8 miles south of Austin, Travis County, on the Lockhart road.
1890	County pit, on south bank of Onion creek on Lockhart road, 8 miles south of Austin, Travis County.
1891	Hole place, 7 miles south of Austin, about ½ mile east of San Antonio road, Travis County.
1892	Jno. Ash pit, 10 miles south of Austin, Travis County.
1893	T. T. Waggoner place, above crossing of San Antonio road, north side of Onion creek, about 10 miles south of Austin, Travis County.
1894	Summerow pit, about 1 mile below the crossing of the San Antonio road on Onion creek, about 10 miles south of Austin.
1895	Johnson Fort road, Zilker pit, near Bee Cave road, close to Colorado river, 3 miles west of Austin, Travis County.
1897	Pit on land of Chas. B. Winn, about 1½ miles west of Austin, and about ½ mile west of I. & G. N. railroad, Travis County.

Laboratory No.	Location
1898	Bledsoe pit, 5 miles south of Austin, Travis County, on Lockhart road.
1899	About 3 miles west of Austin, Travis County, on Bee Cave road.
1900	About 3¾ miles west of Austin, Travis County, on Bee Cave road.
1901	Five miles west of Austin, Travis County, on Bee Cave road.
1902	From 6 miles west of Austin, Travis County, Marshall quarry (Marshall goat ranch).
1929	Just above I. & G. N. railroad bridge, Onion creek, Hays County, 15 miles from Austin, and about ½ mile north of Buda.
1930	Rilander pit, about 14 miles from Austin, on San Antonio-Austin road, Hays County.
1931	Town of Buda, Hays County.
1932	Martin pit, on Buda road between Manchaca and Onion creek, Travis County.
1933	About 6 miles from Austin, Travis County, on upper Manchaca road, near old Oak Hill railroad switch.
1934	About 8 miles south of Austin, Travis County, on Manchaca road.
1935	About ¾ mile west of Manchaca, Travis County, on Bear creek.
1936	Will Birkner, 1 mile west of I. & G. N. railroad and about 12 miles from Austin, Travis County.
1937	Will Birkner's land, upper Austin-Buda road, about 12 miles from Austin, Travis County, and about 1 mile west of I. & G. N. railroad.
1940	About 1 mile north of Watters Park, on A. & N. W. railroad, Travis County, Georgetown road.
1941	About 100 yds. west of A. & N. W. railroad, 1½ miles north of Watters Park, Travis County.
1942	Jno. Brookman place, Georgetown-Round Rock road, 1¾ miles north of Watters Park, A. & N. W. railroad, Travis County.
1943	W. E. McNeese land, about 4 miles south of Round Rock, but in Travis County, on Georgetown-Round Rock road, about 1 mile east of A. & N. W. railroad.
1944	Along Lake Brushy creek, about 200 yds. above I. & G. N. railroad bridge, Williamson County.
1945	Lake Brushy creek, just below I. & G. N. railroad bridge, Williamson County.
1946	G. A. Burkman's land, about ½ mile south and east from I. & G. N. railroad, ¾ mile southeast of Round Rock, Williamson County.

Laboratory No.	Location
1947	About 200 yds. east of I. & G. N. railroad track and south of Round Rock, near city limits, Williamson County.
1948	B. C. Richards's land, on I. & G. N. spur to Georgetown, Williamson County.
1949	B. C. Richards's land, about ¼ mile from Round Rock and Georgetown spur, I. & G. N. railroad, Williamson County.
1950	From 1 to 1¼ miles south of Round Rock, Williamson County, on I. & G. N. main line and McNeill wagon road.
1951	Geo. John's ranch, about 3 miles southwest of Round Rock, Williamson County, near I. & G. N. railroad main line.
1952	I. & G. N. railroad quarry, on right of way, about 1 mile north of McNeill but in Williamson County.
1953	Forstman place, about 1½ miles east of Round Rock, Williamson County, on Lake Brushy creek, and 300 yds. southeast of water tank on I. & G. N. main line. Upper stratum.
1954	Same as 1953, lower stratum.
1955	Otto Granzert, W. J. Fouse pit, about 2 miles east of Round Rock, Williamson County, on I. & G. N. main line.
1956	W. J. Fouse pit, I. & G. N. railroad switch on Brushy creek, about 1½ miles east of Round Rock, in Williamson County.
1957	About 1½ miles east of Round Rock, Williamson County, on Merrill property, and 300 yds. west of I. & G. N. main line, near Fouse's pit.
1958	Austin White Lime Co., McNeil, Travis County, old pit on west side.
1959	Hamilton place, 8 miles northwest of Austin, Travis County, on the Burnet road, and about 500 yds. west of I. & G. N. railroad.
1960	Hamilton place, 8 miles northwest of Austin, Travis County, on Burnet road, and about 800 yds. west of I. & G. N. railroad.
1961	Hamilton place, 8 miles northwest of Austin, Travis County, on Burnet road, and about 1000 yds. west of I. & G. N. railroad.
1962	E. F. Elliott, about 8 1-3 miles northwest of Austin, Travis County, and about 300 yds. west of I. & G. N. railroad.
1963	Frank Cheatham, about 9 miles northwest of Austin, Travis County, and about 300 yds. west of I. & G. N. railroad.
1964	Bird ranch, about 10 miles northwest of Austin, Travis County, and about 200 yds. west of I. & G. N. railroad.
1965	About ½ mile south of Duval sectionhouse, on I. & G. N. railroad, and about 12 miles northwest of Austin, Travis County.

Laboratory No.	Location
1966	From ½ to ¼ mile south of Duval sectionhouse, I. & G. N. railroad, and about 12 miles northwest of Austin, Travis County.
1967	At wagon road crossing of I. & G. N. railroad, first creek north of Duval sectionhouse, about 12 miles northwest of Austin, Travis County.
1968	On Walnut creek, northeast of Duval sectionhouse, I. & G. N. railroad, and about 12 miles northwest of Austin, Travis County, about 150 yds. east of railroad.
1969	J. D. Cahill's land, about ¾ mile south of McNeil station, I. & G. N. railroad, and about 200 yds. from the railroad, in Travis County.
1970	Payton place, about 7¾ miles northwest of Austin, Travis County, and about 500 yds. west of I. & G. N. railroad.
1971	Wilson place, about 7 miles northwest of Austin, Travis County, and 200 yds. west of the I. & G. N. railroad.
1972	About 5½ miles northwest of Austin, on Spicewood Springs road, Travis County.
1973	From ravine west of I. & G. N. railroad, and north of street car line to dam, near Austin, Travis County.
1974	About 350 yds. above Pease Park, on banks of Shoal creek, near Austin, Travis County.
1975	Pease Park road, on east side, near Austin, Travis County.
1976	West side of Shoal creek, near Pease Park road, Austin, Travis County.
1977	Same as 1976, north end of exposure.
1978	From Dittlinger Lime Company, near New Braunfels, Comal County.
1979	Same as 1978.
1980	Same as 1978.
1981	From near Lena Spur, Fayette County. J. C. Melcher, O'Quinn.
1982	Same as 1981.
1983	From J. C. Melcher, O'Quinn, Fayette County.
1984	Brushy creek, 1½ miles north of Round Rock, Williamson County, along I. & G. N. railroad.
1985	Blanco river, Hays County.
2002	Castroville road, on hill west of Leon creek, seven miles west of San Antonio, Bexar County.
2003	Hill west of Leon creek, Castroville road, Bexar County.
2011	Pit on land of Brown Bros., Austin, Travis County, known also as the McBee place, about 3½ miles southeast of Kyle, on Lockhart road, in Hays County.

Laboratory No.	Location
2012	Pit in M. M. Sylers' pasture, on bank of Onion creek, Buda-Kyle mountain road, about ¾ mile southwest of Buda, and about 1-3 mile west of I. & G. N. railroad, in Hays County.
2013	About 3 miles west of Buda, in Hays County, on Buda-Kyle mountain road, about ½ mile west of I. & G. N. railroad.
2014	About 4 miles southwest of Buda, in Hays County, on Buda-Kyle mountain road, about 1 mile west of I. & G. N. railroad.
2015	About 5½ miles southwest of Buda, in Hays County, on Buda-Kyle mountain road, and about 1 mile west of I. & G. N. railroad.
2017	Pit on San Antonio-Austin road, between gin and Manchaca road, about 2½ miles north of Buda, Hays County.
2018	Abandoned pit about 200 yds. west of pit now being worked, 2¾ miles southeast of Kyle, in Hays County, and about 1½ miles east of San Antonio-Austin road, on Lockhart road.
2019	J. A. Heidenreich's old pit, includes hard formation above gravel, Hays County.
2020	J. A. Heidenreich's large pit, about 200 yds. east of pit located in Anal. 2018-19.
2021	Pit on land of Brown Bros., Austin, known also as the McBee place, about 3½ miles southeast of Kyle, in Hays County, on Lockhart road.
2022	Prospect pit, about 100 yds. east of I. & G. N. railroad, about 3½ miles south of Kyle, in Hays County, at 25th mile post. J. B. Donaldson's land.
2023	I. & G. N. railroad cut just north of I. & G. N. bridge over Blanco river, about 4½ miles south of Kyle, Hays County, near Austin-San Antonio road.
2024	F. M. Warnken's land, pit on I. & G. N. railroad spur to Blanco river, 5 miles south of Kyle, Hays County.
2025	Blanco river just below I. & G. N. railroad bridge and the San Antonio-Austin road, about 5 miles south of Kyle, in Hays County.
2026	Two miles west of Kyle, Hays County, on old Government road, about 50 yds. west of road.
2027	Pit about 3½ miles southwest of Kyle, on old Government road, Hays County.
2028	Near No. 2027.
2029	About 3 miles southwest of Kyle, in Hays County, on old Government road.

Laboratory No.	Location
2030	About 1 mile north of Kyle, in Hays County, on San Antonio-Austin road, Jno. Arbour's field, east of and near I. & G. N. railroad.
2031	Eugene Woods' land, about 1¼ miles north of Kyle, in Hays County, on San Antonio-Austin road, about 100 yds. south of road, in creek, and about a mile east of I. & G. N. railroad.
2032	Eugene Woods' land, about 1¼ miles north of Kyle, in Hays County, on San Antonio-Austin road.
2033	Plum Creek, Hays County, about 200 yds. up the creek from bridge on San Antonio-Austin road, Deshay Bunton place.
2034	Deshay Bunton place, on hill about 2½ miles north of Kyle, in Hays County, on San Antonio-Austin road, near two-story house.
2037	Near Mathis, San Patricio County.
2038	Same as 2037.
2049	On Blanco river, spur of M. K. & T. railroad, about 2½ miles northeast of San Marcos, Hays County.
2050	On Blanco river, Hays County, spur of M. K. & T. railroad, about 2½ miles northeast of San Marcos.
2051	About ¾ mile east of Austin-San Antonio road, from county poor farm, Hays County.
2052	About ¾ mile south of wagon bridge over the Blanco river on the San Antonio-Austin road, and about 75 yds. west of I. & G. N. railroad, Hays County.
2053	About ¾ mile east of Austin-San Antonio road, at county poor farm, Hays County.
2054	Frank Johnson's land, about 2 miles southwest of San Marcos, old pit on east side of road, Hays County, on Austin-San Antonio wagon road.
2055	U. Williams's land, about 2¼ miles south of San Marcos, on San Antonio-Austin road, 50 yds. west of I. & G. N. railroad, Hays County.
2056	Jno. Benneck's land, about 1½ miles southwest of San Marcos, 200 yds. north of San Antonio-Austin road, and about ¾ mile northwest of I. & G. N. railroad, Hays County.
2057	Hutchens's land, prospect pit, about 2½ miles southeast of Kyle, about 200 yds. east of I. & G. N. railroad, on San Antonio-Austin road, Hays County.
2065	Swancoat property, about 2¼ miles southwest of San Marcos, on the San Antonio-Austin road, Hays County.
2066	Near Hunter, Comal County, on M. K. & T. railroad.

Laboratory No.	Location
2067	F. Weigraffe property, about 5¾ miles southwest of San Marcos, and about ½ mile northwest of San Antonio-Austin road, in Hays County.
2068	Near Hunter, on M. K. & T. railroad, Comal County.
2069	Specht property, York's Creek, about 300 yds. west of Hunter, Comal County.
2070	About 4 miles southwest of San Marcos, on San Antonio-Austin road, and about ¼ mile northwest of I. & G. N. railroad, Hays County.
2079	Vacant lot on Castell Street, New Braunfels, Comal County, about ¾ mile southwest of county courthouse.
2080	About ¾ mile southwest of Hunter, on bank of York creek at culvert, property of Otto Preusse, Comal County.
2081	About 4 miles west of New Braunfels, on I. & G. N. railroad, and about 1 mile northwest of San Antonio-Austin road, Comal County.
2082	About 1¼ mile southwest of I. & G. N. railroad depot at Hunter, and about 50 yds. below railroad bridge over York's creek, near San Antonio-Austin road, Comal County.
2083	Reischter property, about 3 miles northeast of New Braunfels, on the San Marcos road, and I. & G. N. railroad, and about 200 yds. north of San Antonio-Austin road, Comal County.
2084	Mittendorf's place, about 6 miles northeast of New Braunfels, and 100 yds. east of San Antonio-Austin road, Comal County.
2085	About 5 miles northeast of New Braunfels, on Alligator creek, pit about 200 yds. up creek from San Antonio-Austin road, Comal County, on W. Hausmann's place.
2086	About 1 mile southwest of Hunter on San Antonio-Austin road, at crossing of York's creek, Comal County.
2087	Henry Soechting's place, about 1½ miles southwest of Hunter, and about 100 yds. east of San Antonio-Austin road, Comal County.
2088	About 7½ miles southwest of New Braunfels, and about 75 yds. northwest of San Antonio-Austin road, in lane, Comal County.
2089	Adam Hubertos' place, prospect pit about 10 miles southwest of New Braunfels and about ¼ mile east of San Antonio-Austin road, Comal County.
2090	Frank Hansen's property, 4 miles west of LaGrange, Fayette County, on Buckner's creek.
2091	Louis Reinoseck's land, 3½ miles west of LaGrange, Fayette County, on Buckner's creek.

Laboratory No.	Location
2093	Southwest of New Braunfels, about 4 miles on Comal creek above road crossing, about ¾ mile northwest of P. Schumann's blacksmith shop on San Antonio-Austin road, Comal County.
2094	About 5 miles southwest of New Braunfels, on Comal creek, and about ½ mile northwest of San Antonio-Austin road, opposite station 754, north bank of creek, Comal County.
2095	About 5 miles southwest of New Braunfels, on south side of Comal creek and about ½ mile southwest of San Antonio-Austin road, opposite station 754, Comal County.
2096	Ernstein pit, about 1½ miles east of New Braunfels, on Seguin road, about ¼ mile from San Antonio-Austin road, Comal County.
2097	About 3 miles north of New Braunfels, Comal County, about 500 yds. southeast of Gruene's store.
2098	About 3¼ miles north of New Braunfels, Comal County, and about 500 yds. north of Gruene's store, on old stage road.
2099	Widow Rabe's place, about 5 miles north of New Braunfels, Comal County, on old government road, and about 100 yds. from crossing of wagon road and M. K. & T. railroad.
2105	1½ miles south of Monte Cristo, Hidalgo County.
2116	J. C. Melcher, O'Quinn, Fayette County.
2130	Pit on University land, road to Austin dam, Travis County.
2132	New pit about 7½ miles north from San Antonio on San Antonio-Austin road.
2133	Same as 2132.
2134	Salado creek, about 7½ miles north of San Antonio and about 1/3 mile east of post road, Bexar County.
2135	West of Salado creek, 6½ miles northeast of San Antonio, Darrity road, commencing on banks of creek, Bexar County.
2136	Prospect pits, 4½ miles east of San Antonio, Bexar County.
2137	Six miles south of east of San Antonio, about 50 yds. south of Gonzales County road, in Bexar County.
2138	North bank of Cibolo creek, from test hole, about 17 miles north of San Antonio, on government highway, Guadalupe County.
2139	About 8.2 miles northeast of San Antonio on San Antonio-Austin road; prospect pit about 4 feet deeper than No. 2132-33, Bexar County.
2140	Bed of Cibolo creek, about 17 miles north of San Antonio and about 50 yds. up creek from crossing of government highway.
2149	From surface of Maney pit, Smithville, Bastrop County.

Laboratory No.	Location
2166	Half mile from Main Street, Smithville, Bastrop County, on tracks of M. K. & T. railroad, 3 ft. below surface, Maney pit. See Plate XI.
2167	M. E. Maney pit, Smithville, Bastrop County.
2168	C. H. Chamberlin, Dallas, from Trinity river valley, directly north of Grand Prairie, Dallas County.
2170	From Alvord, Wise County.
2171	Pit east of Granite Mountain, about 50 feet east of H. & T. C. railroad tracks, south of Granite Mountain station, Burnet County, on property of Darragh & Caterson.
2172	Pit about 100 yds. north of pit represented by No. 2171, and about 75 ft. east of H. & T. C. railroad tracks, south of Granite Mountain station, Burnet County, property of Darragh & Caterson.
2173	Pit about 50 ft. west of the Horn Spur, northeast from Granite Mountain, on H. & T. C. railroad, Burnet County, property of Darragh & Caterson.
2174	South end of Horn Spur, from what is known as the S. C. Cockburn quarry at Granite Mountain, property of Darragh & Caterson, Burnet County.
2175	Bank below wagon road from road to dam to Hartkopf's dairy, along road to dam, south of two-story stone house, Travis County.
2176	Same as 2175, only from bank above road.
2177	Pit on land of Mrs. Stokes, Webberville road, 1½ miles from Austin, Travis County.
2207	Pit ¼ mile beyond city limits, extension of Chinquapin Avenue, east of Austin, Travis County, Carl Hyltin's property.
2211	From Rogers's quarry, Eastland County.
2217	From Tiffin quarries, Ranger, Eastland County.
2231	From Tiffin quarry, Eastland County. See Plate XIII.
2252	Murray pit, 4 miles east of Troy, Bell County.
2259	Near Duval sectionhouse, and about 200 yds. west of I. & G. N. railroad, Travis County.
2260	From William Veich, Denison, Grayson County.
2262	Near Nursery, Victoria County, property of Jno. McCrabb Callahan & Crawford pit.
2271	Pit 6 miles west of Temple, Bell County, near old Howard road, on property of J. S. Fowler (colored).
2286	From Comal Rock Co., New Braunfels, Comal County.
2308	On Crystal City division of S. A. U. & G. railroad, about 2 miles northwest of New Pleasanton, Atascosa County.
2310	From Fred J. Shutt, Duncanville, Dallas County.

Laboratory No.	Location
2311	Same as 2310.
2313	Tadlock's pit, near Camp Mabry, Travis County.
2314	Near Austin, Travis County.
2319	Property of University of Texas, near Austin, Travis County.
2320	Same as 2319.
2321	Same as 2319.
2323	Property of W. N. Hessey, on Cameron road, north of Austin city limits, Travis County.
2324	Near New Braunfels, Comal County.
2325	Same as 2324.
2326	Same as 2324.
2327	Same as 2324.
2330	Trinity Gravel Co., Fort Worth.
2345	Texarkana, Bowie County, property of M. D. Tilson.
2346	Same as 2345.
2352	Pit of F. A. Heep, Travis County, about ½ mile to left of Station 550, on San Antonio-Austin road.
2353	Pit of Heywood Barr, opposite Station 429, Travis County, on San Antonio-Austin road.
2355	Travis County, ¼ mile up Onion creek from San Antonio-Austin road.
2374	Tom Norton's property, Llano, Llano County.
2452	About 5 miles north of Denton, and about 3 miles west of M. K & T. railroad, property of Jack Pass, Denton County.
2453	At Carrollton, on Dallas branch of M. K. & T. railroad, Dallas County.
2454	R. T. Yearby's land, about 3 miles southwest of Denton, Denton County, and about ¼ mile west of M. K. & T. railroad.
2456	C. B. Grant's land, 3.1 miles southwest of Denton, Denton County, and ½ mile west of M. K. & T. railroad.
2457	Cut of I. & G. N. railroad about 3½ miles southwest of Austin, Travis County.
2458	G. B. Hagan's land, about 5½ miles west of Denton, Denton County, on main Decatur and Denton wagon road.
2466	J. C. Parr, Denton County, about 2½ miles south of Denton and about 50 yds. west from M. K. & T. railroad.
2467	Gurley & Johnson pit, Denton, Denton County.
2468	Same as 2467.
2469	About 3½ miles southwest of Denton, and about ¼ mile west of M. K. & T. railroad, county property, Denton County.
2470	From McKinney, Collin County.

Laboratory No.	Location
2482	Property of P. T. Bost, about 4¼ miles south of San Marcos, about 200 yds. west of I. & G. N. railroad, and about the same distance east of San Antonio-Austin road, Hays County.
2483	Hadden estate, Deaf Smith County, near Hereford.
2484	Property of J. C. Burch, Mineral Wells, Palo Pinto County.
2496	Pilot Knob, 10 miles southeast of Austin, Travis County.
2518	From along public road, Clarksville, Red River County.
2520	Nine miles north of Waco, McLennan County.
2535	Property of Emory Palmer, Wood County, near Mineola.
2536	Property of Gus Caton, or B. Hurt, near Mineola, Wood County.
2537	Property of A. Patton, near Mineola, Wood County.
2538	Club Lake, near Mineola, Wood County.
2539	Herington Survey, 6 miles east of Mineola, Wood County.
2545	About 5 miles west of Marshall, on Tyler road, Harrison County, Anderson property.
2546	Five miles south of Marshall, Harrison County, from ridge just west of No. 2547.
2547	About 5 miles south of Marshall, and about 2 miles west of the Carthage road, county property of Harrison County.
2548	Roseborough Springs road, about 2½ miles southwest of Marshall, Harrison County.
2557	Property of Dr. Patton, on Mineola and Varner road, about 5¼ miles east of Mineola, Wood County.
2558	County property, Wood County, on Mineola road, 1 mile west from red sand store and about 7 miles east from Mineola.
2559	Creek about 4½ miles northeast of Mineola, Wood County, and about ½ mile west of Green Bridge.
2560	Property of Dr. Patton, about 5 miles east of Mineola, about 200 yds. north of Varner and Mineola road, Wood County.
2561	County property, side of road on Hawkin and Hainesville road, opposite oil well, about 2 miles southeast of Hainesville, Wood County.
2562	Property of Mineola Hunting & Fishing Club, about 5½ miles east of Mineola, about ¼ mile north of Mineola and Varner road, at tank, Wood County.
2566	About 3 miles west of Golden, Wood County, about ¼ mile south of M. K. & T. railroad, near switch.
2567	Riley Stewart estate, from Stewart Hill, about 300 yds. west of Mineola and Tyler road, and about 6½ miles south of Mineola, Wood County.

Laboratory No.	Location
2568	Property of Eliza Copeland, about 150 yds. up creek from wooden bridge on Dallas and Shreveport road, about 5½ miles south of Mineola, Wood County.
2640	Barber & Evans farm, 5 miles east of Kyle, on Kyle-Goforth road, Hays County. Also known as Turner farm land.
2645	Property of O. Slaughter, Collin County, near Anna.
2648	Property of W. C. Buford, Rusk County, 1 mile north of Henderson courthouse on Longview road.
2649	Same as 2648.
2650	Property of Bruce Hamlett, 2½ miles northwest of Henderson on the I. & G. N. railroad, Rusk County.
2651	P. D. Chapman's property, ¾ mile north of courthouse at Henderson, on Longview road, Rusk County.
2652	Depot Street, Henderson, Rusk County.
2653	Property of Will Bromley, 1½ miles northeast of Henderson courthouse, on county road, Rusk County.
2654	East Street, Henderson, Rusk County, city property.
2656	City property, Palestine, Anderson County, about 1 mile northeast of Sycamore Street, just outside city limits.
2657	City property, Palestine, Anderson County, on Spring Street.
2658	F. H. Devenport property, about 2 miles northeast of Palestine, on Neches road, Anderson County.
2659	Property of T. B. Greenwood, 1¼ miles east of Pasey Bridge road, Anderson County, from Palestine.
2673	Property of D. C. Perry, known as Perry Mountain, 3 miles west of Palestine, about ½ mile north of West Point road, Anderson County.
2674	Thos. Crossin property, about 2½ miles west of Palestine, 300 yds. west of Crossin pump station, and 50 yds. north of county road, near Palestine, Anderson County.
2675	Ten miles south and west of Llano, old Jno. Billingsley place (now owned by Albert Rickerson), Llano County.

LOCATIONS OF MATERIALS TESTED BY OFFICE OF PUBLIC ROADS, U. S. DEPARTMENT OF AGRICULTURE,

Up to September 1, 1915, Included in Tables.

Laboratory No.	Location
1199	San Antonio, Bexar County.
1200	Same as 1199.
1201	Same as 1199.
1202	Same as 1199.
1229	Same as 1199.
1479	Denison, Grayson County.
1480	Same as 1479.
1499	Grayville quarry, Washington County.
1500	Sandpit Station, Burleson County.
1958	Marshall, Harrison County.
2084	A. S. Eylar, El Paso, El Paso County.
2185	Same as 2084.
2685	Hillsboro, Hill County.
2706	Round Rock, Williamson County.
2707	Same as 2706.
2708	Same as 2706.
3142	Denison, Grayson County.
3147	Paris, Lamar County.
3413	Denison, Grayson County.
3414	Same as 3413.
3727	L. T. Botto, Box 597, El Paso, El Paso County.
3869	Jacksboro, Jack County.
4131	Mineral Wells, Palo Pinto County.
4133	County property of Tarrant County.
4134	Same as 4133.
4327	Maryneal, Nolan County.
4412	Bridgeport, Wise County.
4532	Sweetwater, Nolan County.
5395	Stewarton, Jack County.
5455	Taylor County.
5532	Paris, Lamar County.
5642	Denison, Grayson County.
5709	Sherman, Grayson County.
5851	Denison, Grayson County.
5852	Same as 5851.
5900	Celina Mill & Elevator Co., Celina, Collin County.

Laboratory No.	Location
5901	Same as 5900.
5936	Trinity Mills, Dallas County.
5937	Sherman, Grayson County.
5938	Same as 5937.
5939	Four miles west of Gainesville, Cooke County.
5955	Richland, Navarro County.
5975	Sherman, Grayson County.
6314	Terrell, Kaufman County.
6329	Duval County.
6396	Tyler, Smith County.
6398	Same as 6396.
6579	Mineral Wells, Palo Pinto County.
6600	Bridgeport, Wise County.
6667	Same as 6600.
6679	Pit near Midway, south side of road, Bell County.
6680	Santa Fe pit, north of road at Midway, Bell County.
6681	Pit near Belton, Bell County.
6683	Chico, Wise County.
6684	Same as 6683.
6753	Property of W. J. Hipp, Houston, in Colorado County.
6754	Property of August Ilse, Columbus, Colorado County.
6914	Robertson County.
6915	Robertson County.
7015	Chief, Kaufman County.
7016	Elmo, Kaufman County.
7070	Navarro County.
7129	Uvalde County, Knippa.
7146	Hearne, Robertson County.
7147	Same as 7146.
7190	Mt. Sterling, Montgomery County.
7209	Richland, Navarro County.
7224	Tehuacana, Limestone County.
7242	Wise County.
7297	Dublin, Erath County.
7331	Jack County.
7332	Jack County.
7609	New Braunfels, Comal County.
7905	San Marcos, Hays County.
8591	Springfield Rock Co., Mexia, Limestone County.
8805	Pit No. 1, Yoakum, DeWitt County.
8806	Pit No. 2, Yoakum, DeWitt County.